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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT NAIROBI,--ETC(U)
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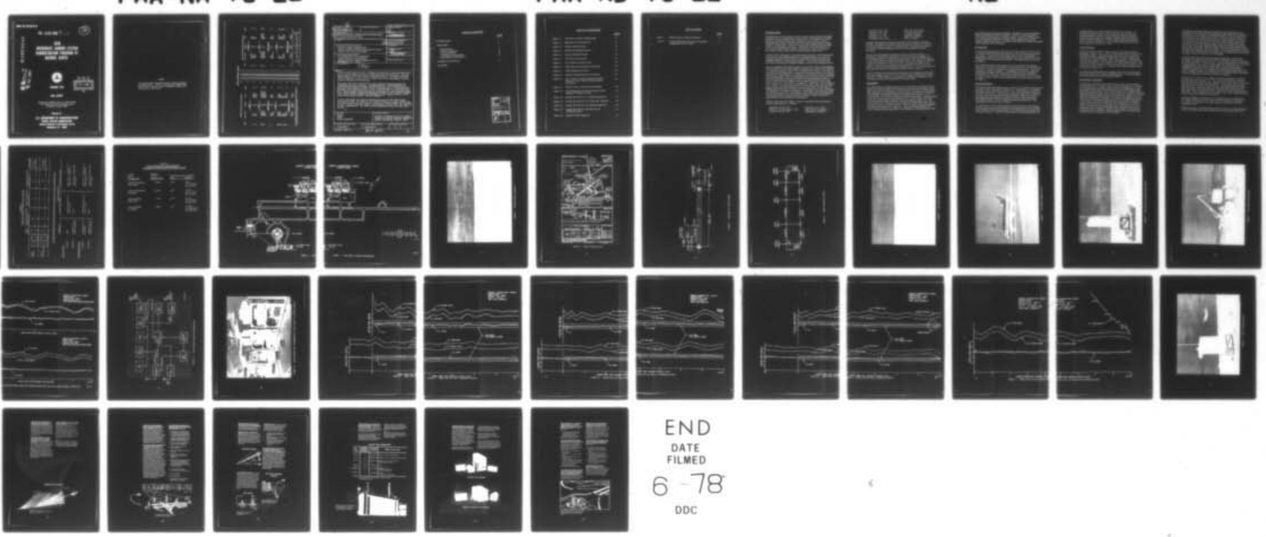

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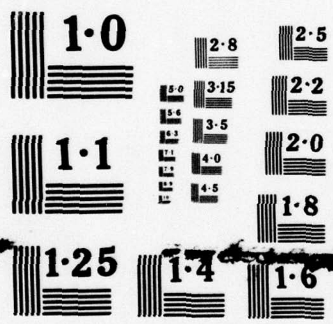

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MICROCOPY RESOLUTION TEST CHART

Report No. FAA-RD-78-22

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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT NAIROBI, KENYA

FEBRUARY 1978

FINAL REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

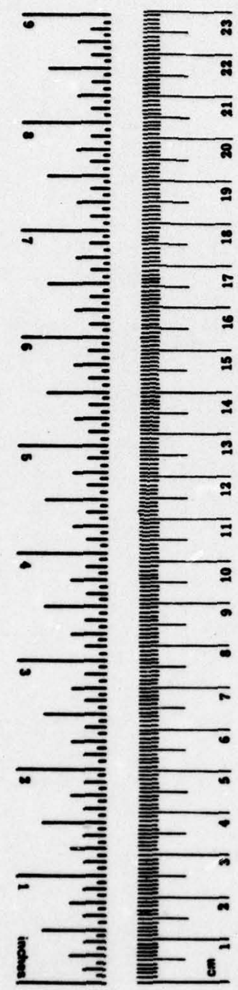
NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

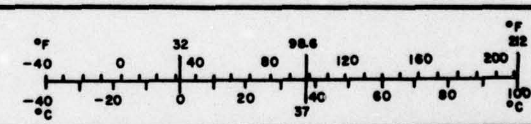
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. (18) (19) FAA-RD-78-22	2. Government Accession No.	3. Recipient's Catalog No. (11)
4. Title and Subtitle (6) TRSB Microwave Landing System Demonstration Program at Nairobi, Kenya.		5. Report Date February 1978
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No. (14) FAA-NA-78-22
9. Performing Organization Name and Address Federal Aviation Administration National Aviation Facilities Experimental Center Atlantic City, New Jersey 08405		10. Work Unit No.
		11. Contract or Grant No. (9)
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590		13. Type of Report and Period Covered Final Report. Feb. 19, 1978 - Feb. 25 1978
		14. Sponsoring Agency Code
15. Supplementary Notes (12) 46p.		

16. Abstract

The operational demonstration at Embakasi International Airport serving Nairobi, Kenya, was the ninth in a series of TRSB worldwide demonstrations. Previous demonstrations of the TRSB "Small Community System," the most economical TRSB configuration, were held at five other sites in the United States, Central America, Europe, and West Africa.

The system was flown to Nairobi in an FAA Boeing 727 testbed aircraft and installed on the same runway as a commissioned ILS. Data acquisition and operational demonstration flights were flown with the FAA B-727 aircraft over a period of 5 days (February 20-24, 1978). During the flights, a radio telemetry theodolite and an optical electronic tracker were used for aircraft space-position data. Flight profiles included straight-in approaches at various elevation angles, level runs at 1500-feet altitude on centerline, and ±10-degrees offsets, and 10-nautical mile partial orbits at 3500-feet altitude.

+ or -

Results of the flight tests indicate that the performance of the TRSB "Small Community System" was within the U.S. Phase III Program design requirements, the ICAO "reduced capability system" requirements, and the ICAO "full capability system" requirements. The TRSB system installation did not adversely affect the ILS.

17. Key Words Nairobi TRSB Small Community	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	42	

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INTRODUCTION

During the past several years, extensive engineering evaluation and flight testing has been accomplished on Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) equipments at the Federal Aviation Administration's (FAA) National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, and at the Auxiliary Naval Landing Field, Crows Landing, California. TRSB MLS is the United States and Australian (INTER SCAN) candidate submission to ICAO as the future all-weather landing system which would eventually replace ILS.

In March 1977, following a 15-month period of intensive and comprehensive assessment of all competing microwave landing systems, the ICAO All Weather Operations Panel (AWOP) recommended TRSB as the preferred candidate system for international adoption. This assessment involved more than 100 leading international experts in microwave landing systems.

The Air Navigation Commission (ANC) reviewed the AWOP recommendation and forwarded it to the ICAO Council, whereupon the Council has scheduled a worldwide meeting for April 1978, to address the question of selecting the new international standard for an approach and landing system to eventually replace ILS. In the interim, in consonance with the ICAO Council suggestion that proposing States carry out demonstrations at operational airports, the FAA has developed a program to conduct operational demonstrations of several TRSB hardware configurations at selected airports in the United States and abroad. (Hereafter for simplicity, "TRSB MLS" will be referred to as "TRSB.") These demonstrations are intended to show that the TRSB signal format and system design are mature and satisfy the full range of requirements from general aviation use to scheduled air carrier operations for Category I to Category III autoland. Additionally, these demonstrations provide opportunities for representatives and officials of the international aviation community to gain first hand knowledge of TRSB MLS and its applicability to their particular requirements.

Nairobi, Kenya was the ninth in a series of operational demonstrations. The previous eight are as follows:

September 28-30, 1977	Cape May, N.J., USA
October 31 to November 4, 1977	Buenos Aires, Argentina
November 24-25, 1977	Tegucigalpa, Honduras

December 5-13, 1977	JFK, New York, USA
January 23-24, 1978	Kristiansand, Norway
February 1-3, 1978	Brussels, Belgium
February 1-3, 1978	Charleroi, Belgium
February 14-15, 1978	Dakar, Senegal

Embakasi International Airport, the largest of three airports serving Nairobi, the capital city of Kenya, has one runway (06/24), 4117 meters (13,507 feet) long by 45 meters (148 feet) wide. The other two airports are Wilson Aerodrome (general aviation) and Eastleigh Aerodrome (military).

A plan view of Embakasi International Airport is shown in Figure 1. Runway 06 is equipped for Category I service with approach lights, an ILS (including outer and middle marker beacons), and a VOR-DME-NDB. A new control tower and terminal building south of the runway are scheduled to open for operations on March 14, 1978. The general topology in the vicinity of the airport is relatively flat, especially the approach area to Runway 06 which extends into Nairobi National Park. A view of the approach area from the Runway 06 landing threshold is shown in Figure 2.

About 25 airlines (national and international) serve Embakasi Airport with aircraft ranging in size from DC-10 and B-747 wide-bodied jets to a DH-6 twin otter. Airline flights are scheduled for daylight and nighttime hours with the air traffic tower operating on a 24-hour basis.

DISCUSSION

The TRSB system configuration selected for installation in Nairobi was the "Small Community System" which had previously been demonstrated at five other sites in the United States, Central America, Europe, and West Africa. This equipment was manufactured by the Bendix Corporation's Communications Division, in accordance with FAA specifications (Table 1). It is representative of the most economical system configuration, and was designed to provide azimuth proportional guidance over an area of plus and minus 10 degrees about runway centerline, with directional guidance (i.e., fly left or right from 10 degrees out to 40 degrees on either side of the runway centerline similar to an ILS localizer). The elevation proportional guidance extends from 2 degrees to 15 degrees. System coverage distance is at least 20 nautical miles under heavy rain conditions, and much greater under

less stringent environmental conditions. Basically, the small community TRSB was designed to provide Category I service on most runways in most airport environments. Guidance quality, however, has been shown to be considerably better than Category I ILS requirements and will support autoland operations. Descriptive information on TRSB is presented in the Appendix to this document.

Site Selection

A three-man team from the FAA was in Nairobi, January 11 to 14, 1978, to conduct initial discussions and perform a survey of prospective equipment sites. A site survey of the airport did not reveal any peculiar geographical conditions and it was decided to use the same runway as the ILS because of prevailing wind conditions. The approach plate is shown in Figure 3.

The azimuth subsystem was placed as far away from the ILS localizer (toward the runway) as obstruction criteria would allow, and the elevation subsystem was placed alongside the ILS glide slope antenna. Exact site locations are shown in Figure 4. Although the terrain is generally flat in the airport vicinity, the runway has a downslope from the landing threshold to the stop end. An elevation profile of Runway 06/24 is shown in Figure 5, and a view from the azimuth site toward the runway is shown in Figure 6.

System Installation

The TRSB "Small Community System" arrived by air in the FAA Boeing 727 aircraft (N-40) at midnight on February 17, 1978 (Figure 7). Equipment unloading commenced on February 19, 1978, after the flight and ground crew had 1-day's rest. The elevation equipment (Figure 8) was installed the same day. Metal platforms (used at previous sites) were used as mounting foundations instead of concrete because of time limitations. The monitor masts were also mounted on aluminum platforms. The installation process is shown in Figure 9.

On February 20, 1978, a flight inspection was performed with the FAA aircraft on the ILS localizer before the azimuth subsystem was installed. Kenya officials from the Directorate of Civil Aviation were on board the aircraft for the test. After the initial flight, the azimuth equipment was

installed (Figure 10) and the flight inspection was repeated. No degradation of the localizer course structure was caused by the azimuth equipment, and the course width was slightly broadened (by less than 0.2 degrees). Flight recordings of the ILS localizer course structure without and with the TRSB azimuth equipment in place are shown in Figure 11. The azimuth and elevation systems were aligned on February 21, 1978.

Airborne System

The B-727 airborne TRSB system consisted of the following dual equipment: angle receiver, course direction indicators, and precision DME interrogators. Instrumentation required for data acquisition consisted of a data multiplexer, digital data recorder, analog video recorder, strip chart recorder, time code generator, VHF telemetry receiver/demodulator, and a modified UHF glide slope receiver. The interrelation of the airborne TRSB system with the B-727 flight control system, is shown in Figure 12, while the data instrumentation system is depicted in Figure 13.

An omni-directional antenna is mounted on the aircraft fuselage just above the center of the cockpit windshield (Figure 7) and was utilized for all operational and data acquisition flights.

Performance Assessment

Ground based tracking for the TRSB demonstrations was provided by two different types of optical trackers used interchangeably at azimuth and elevation sites as requirements dictated. Simultaneous tracking of azimuth and elevation was generally provided for all flights except during the demonstrations. One of the trackers was a manually operated radio-telemetry theodolite (RTT), used to transmit azimuth or elevation angle position data (depending upon its siting for the flight) to the aircraft via a transmitter operating on an unused UHF glideslope channel (329.0 MHz). The second tracking system was an optical electronic tracker manufactured by British Aircraft Corporation of Australia, designed to automatically or manually track a light source on the aircraft. However, the nose-wheel light used as the light source was inadequate for the tracker to operate in the automatic mode, and all tracking was done manually. Angular position data was telemetered to the aircraft on a frequency of 126.25 MHz.

During data acquisition flights, the portable tracker equipment were positioned at the respective TRSB azimuth and elevation sites as follows: Azimuth site on the antenna(s) radiation centerline and 36.6 meters (120 feet) in front of the antenna phase center (to clear the monitor antenna); at the elevation site directly alongside the elevation antenna 2.82 meters (9.25 feet) closer to the runway. The RTT tracker optical center was 0.69 meters (2.25 feet) below the phase center of the elevation antenna. Because of RTT tracker signal problems inside the middle marker when used at the azimuth site, the RTT tracker was used primarily for elevation tracking while the optical electronic tracker was used primarily for azimuth tracking. All of the demonstration flights were tracked by the RTT because the optical electronic tracker was not available.

In the aircraft, the received analog tracker angle data, azimuth and elevation, was subtracted from the TRSB azimuth and elevation angle data to provide a measure of system error. In each case (azimuth and elevation), the angle difference as well as tracker angle and TRSB angle were recorded on light sensitive strip chart recorder paper on an analog recorder. Additionally, airborne received angle data from the optical electronic tracker in digital format was recorded with TRSB digital angle data, DME data, and time code data on a digital recorder to facilitate greater flexibility in data processing and analysis at NAFEC as required.

Figures 14, 15, 16 and 17 are copies of airborne strip chart recordings for four runs from February 21, 1978. Each of these figures contains a reproduced trace of tracker angle, TRSB receiver angle, and error between the two, for the elevation and azimuth axes. In the error plots, small alignment bias errors have been removed. The longitudinal axis of these plots represents range from Runway 06 threshold determined from the field DME which is located behind the azimuth site (3.2nm from Runway 06 threshold). ICAO (AWOP) total error limits for the "full capability system" (Table 2) have been included on the figures.

Referring to Figures 14 through 17, it is apparent that the TRSB Small Community System errors are within the ICAO (AWOP) error limits of $\pm$ 0.1 degree in elevation and $\pm$ 0.076 degree in azimuth for the "full capability system."

System coverage was checked during clockwise (CW) and counterclockwise (CCW) 10-nautical mile partial orbits flown at 1070 meters (3500 feet)

altitude. The reference angles were obtained from the field VOR and translated to the respective azimuth or elevation site. System flags indicated valid data beyond ± 45 degrees for azimuth and ± 70 degrees for elevation.

Operational Demonstrations

The TRSB operational demonstration briefings and flights were held on February 23 and 24, 1978, with 118 registered attendees. AFRAA officials, representatives from four countries, eight airlines, and news media personnel, were in attendance. One-hundred attendees flew on the seven demonstration flights.

The FAA Boeing 727 aircraft was used for the demonstration flights. Each demonstration flight consisted of three approaches initiated from 10 nautical miles at elevation angles of 3, 3.5, and 4 degrees. The 4-degree approach was auto-coupled and generally flown in the coupled mode to below 50 feet altitude before the auto-pilot was disengaged. Standard procedure is to disengage the auto-pilot at 200 feet altitude when ILS guidance is employed. There was no filtering of the TRSB receiver output angle data before it was fed to the auto-pilot. The 3 and 3.5 - degree approaches were flown manually, with the 3-degree approach terminating in a full-stop landing. The demonstration approaches were tracked in only one axis. A typical tracked approach is shown in Figure 18.

On February 25, 1978, the day following the final demonstration, the TRSB system was dismantled and loaded on the aircraft.

SUMMARY OF RESULTS

The TRSB system discussed in this document is representative of a simple, economical configuration of TRSB hardware referred to as a "Small Community System" within the FAA. In addition to the economical design feature, the information presented indicates:

1. Performance of the TRSB system was within ICAO "reduced capability system" requirements and the "full capability system" requirements.

2. The TRSB "Small Community System" was demonstrated to meet its design specifications.

3. The TRSB system can be used on the same runway as ILS without adversely affecting ILS performance.

4. The TRSB system required minimal site preparation and installation time.

TABLE 1.
TRSB ACCURACY, PHASE III SYSTEMS

			BIAS (DEG.)	PATH FOLLOWING NOISE (DEG.)	PATH FOLLOWING ERROR (DEG.)	CONTROL MOTION NOISE (DEG.)	REMARKS
Basic Narrow	AZ	SPEC	.19	.08	.2	.07	at 50' on 2.5° G/S
	EL	SPEC	.08	.09	.12	.05	
Small Community	AZ	SPEC	.29	.15	.33	.10	at 150' on 2.5° G/S
	EL	SPEC	.11	.12	.16	.10	

NOTES ON TRSB ALLOWABLE PFE DEGRADATIONS (PHASE III CONTRACTS)

	PFE Degradation W/Distance	PFE Degradation W/Azimuth Angle	PFE Degradation W/Elevation Angle
Basic Narrow			
Azimuth	None	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 20°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 20°
Small Community			
Azimuth	Linearly to 0.4° at 20 NM	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 15°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 15°

TABLE 2

ICAO (AWOP) FULL AND REDUCED CAPABILITY CONFIGURATION ERROR LIMITS

AWOP System Configuration	Distance to Error Window (Feet)	Permitted Error (2 Sigma) Feet	Degrees
Reduced Capability (Elevation)	4,000	± 10	0.14 ± 0.10 noise ± 0.10 bias
Reduced Capability (Azimuth	10,000	± 40	± 0.23 ± 0.16 noise ± 0.16 bias
Full Capability (Elevation)	1,145	±2.0	± 0.10 ± 0.07 noise ± 0.07 bias
Full Capability (Azimuth)	15,000	± 20	± 0.076 ± 0.054 noise ± 0.054 bias

EMBAKASI INTERNATIONA
NAIROBI, KENY

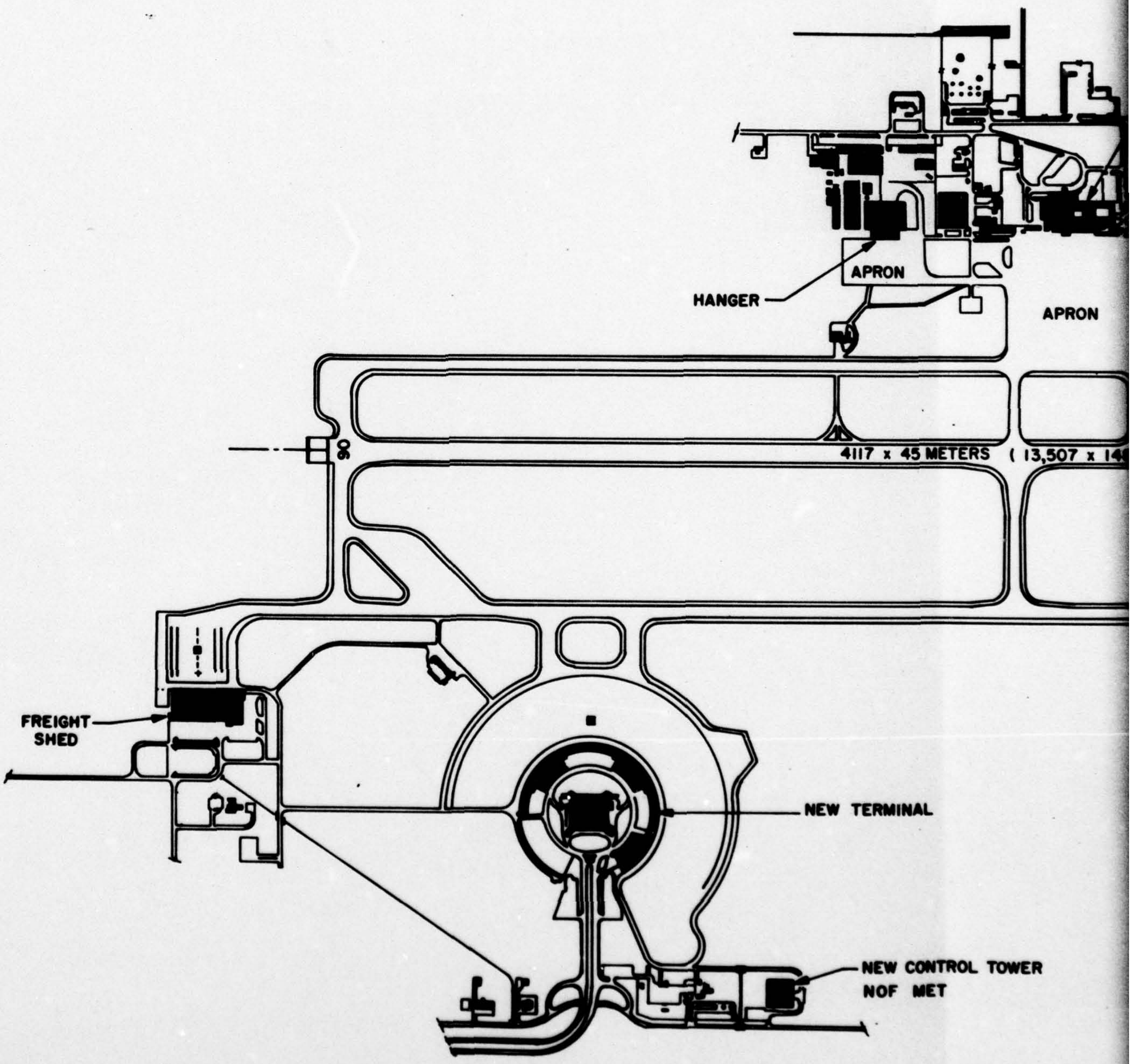

FIGURE 1. PLAN

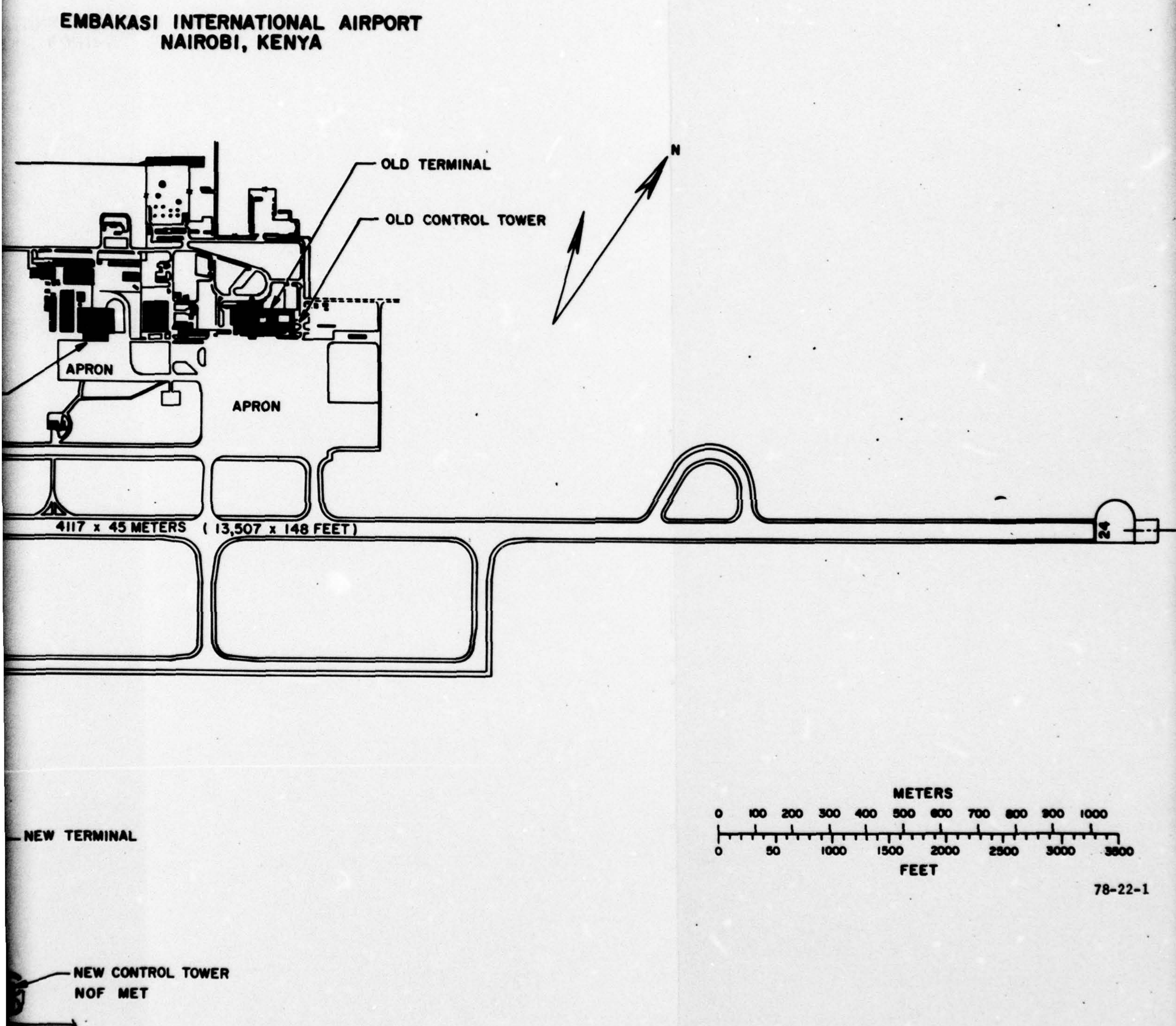

FIGURE 1. PLAN VIEW OF AIRPORT CONFIGURATION

2

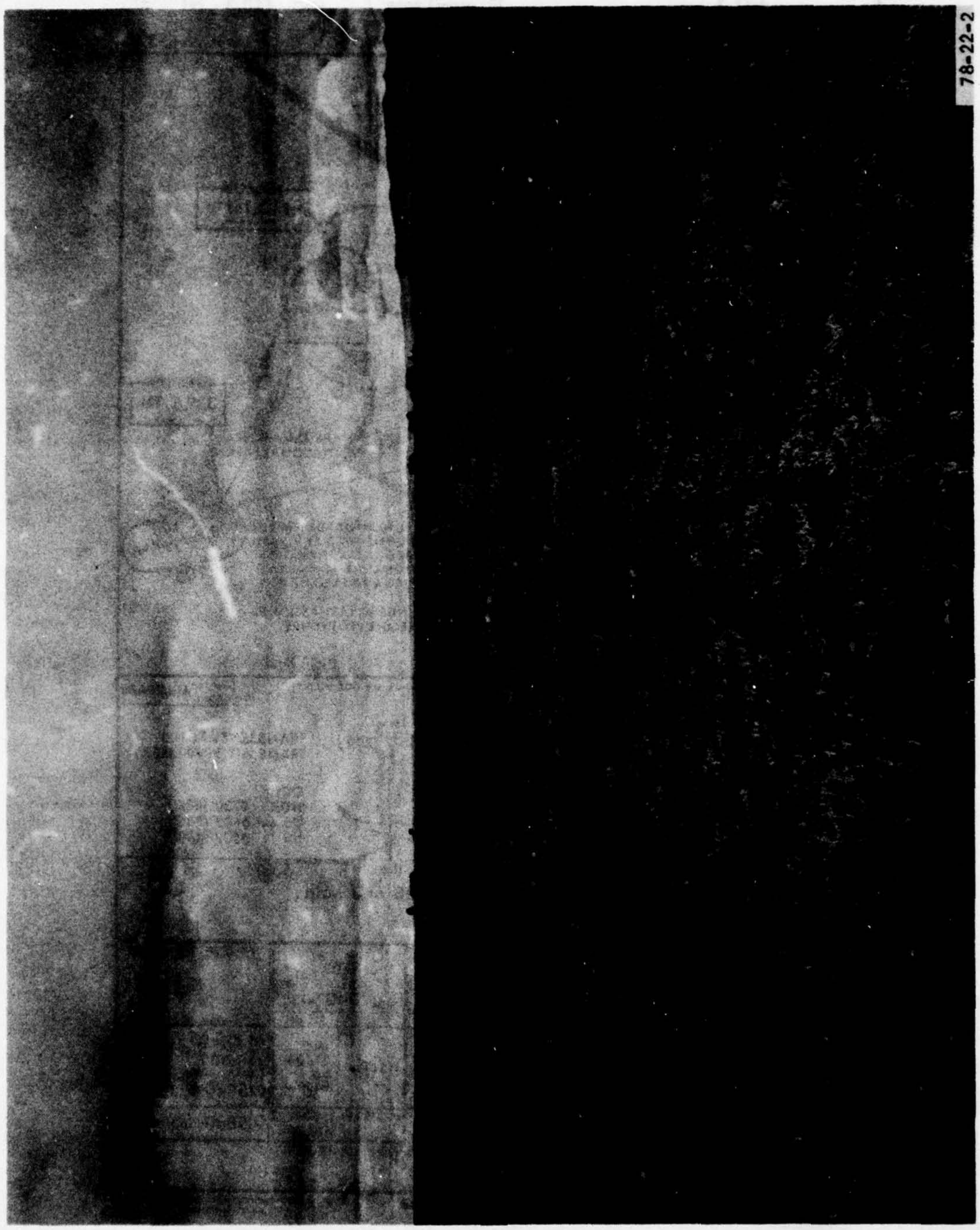

FIGURE 2. APPROACH AREA TO RUNWAY 06

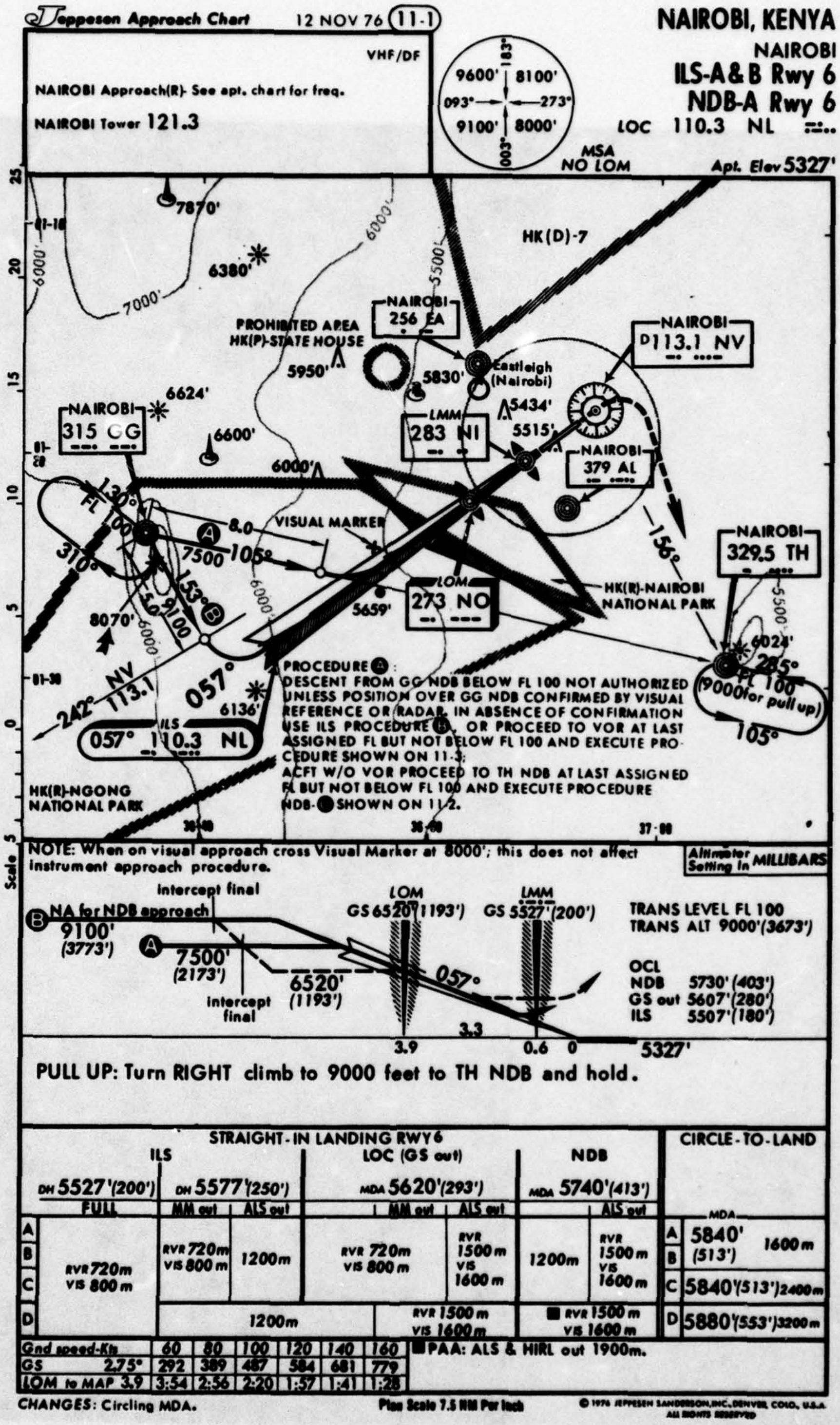

FIGURE 3. RUNWAY APPROACH PLATE

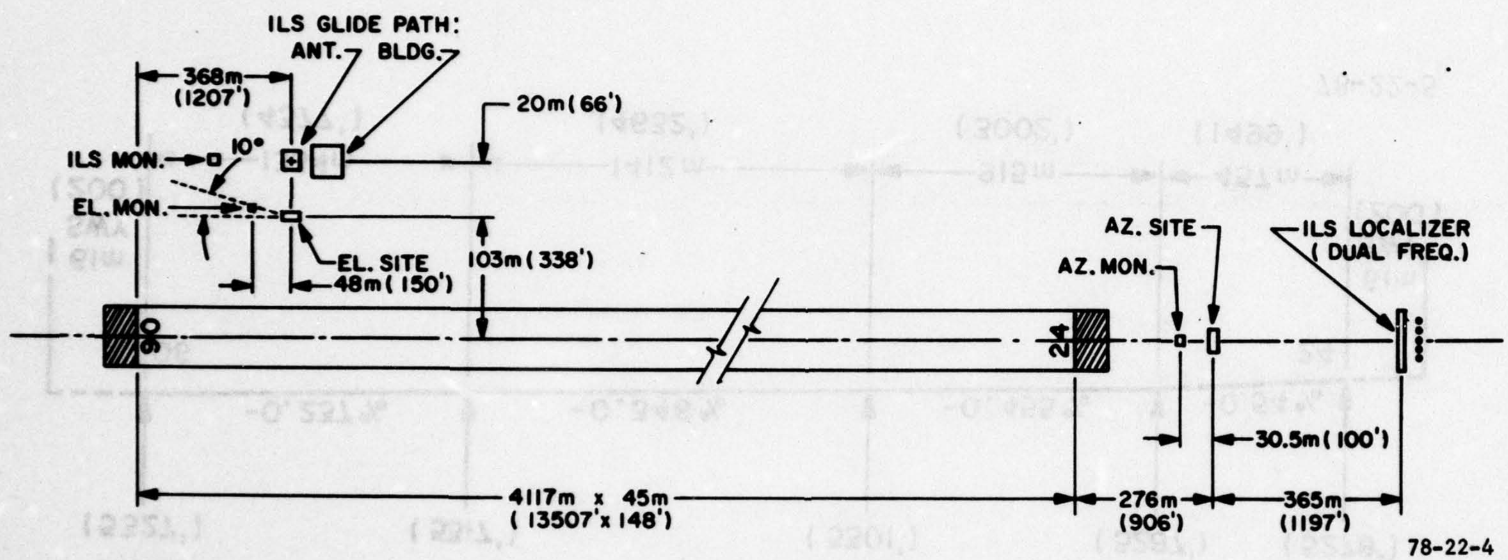

FIGURE 4. TRSB AND ILS SITING DIAGRAM

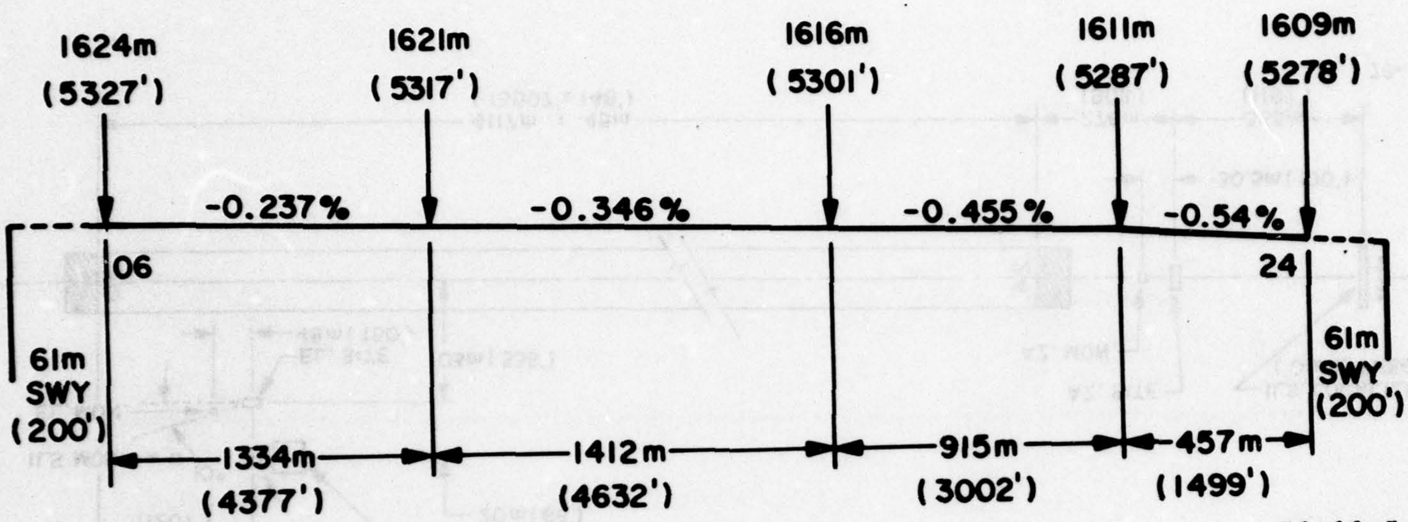

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FIGURE 5. RUNWAY ELEVATION PROFILE

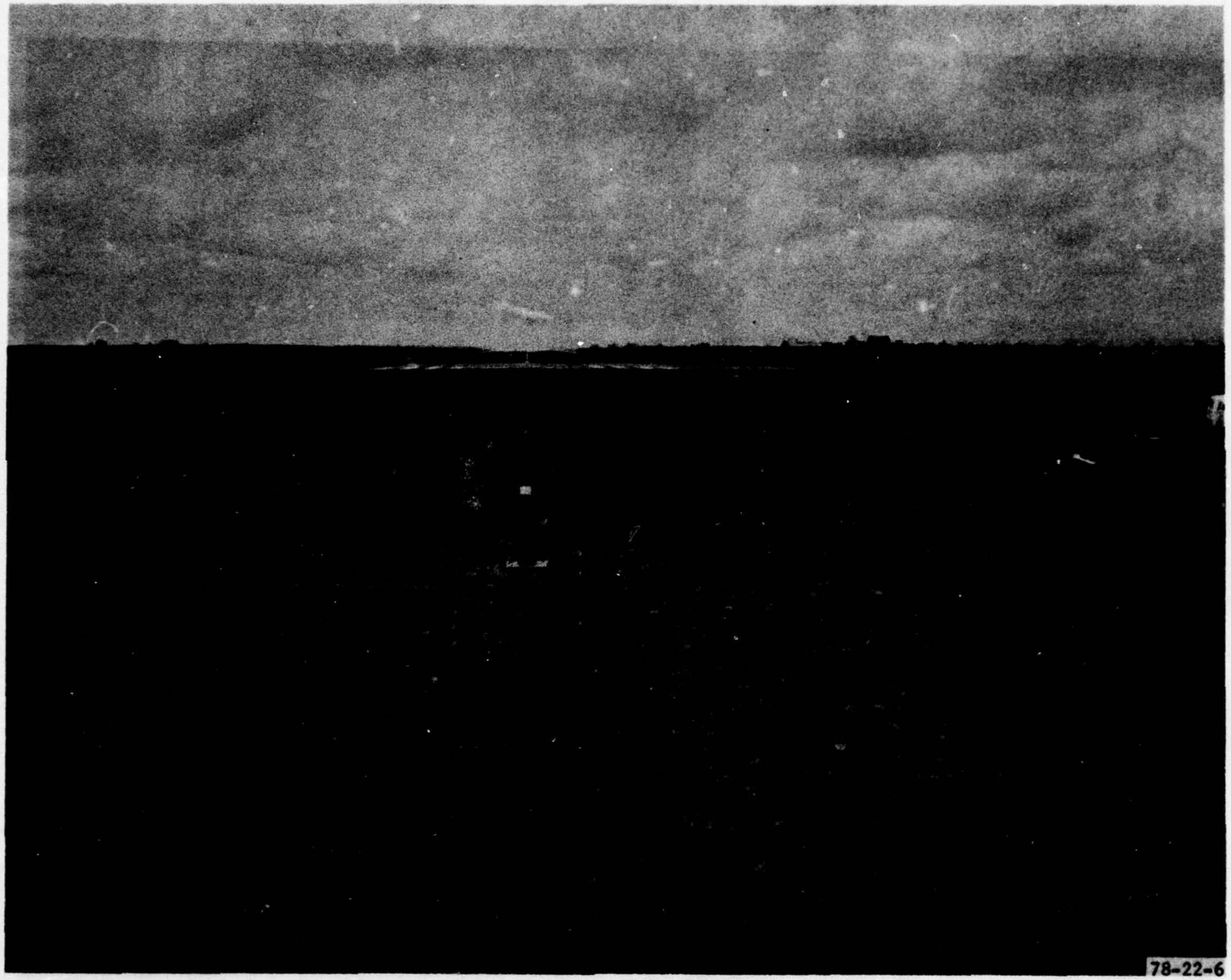


FIGURE 6. VIEW FROM AZIMUTH SITE

FIGURE 7. FAA TESTBED AIRCRAFT (N-40)

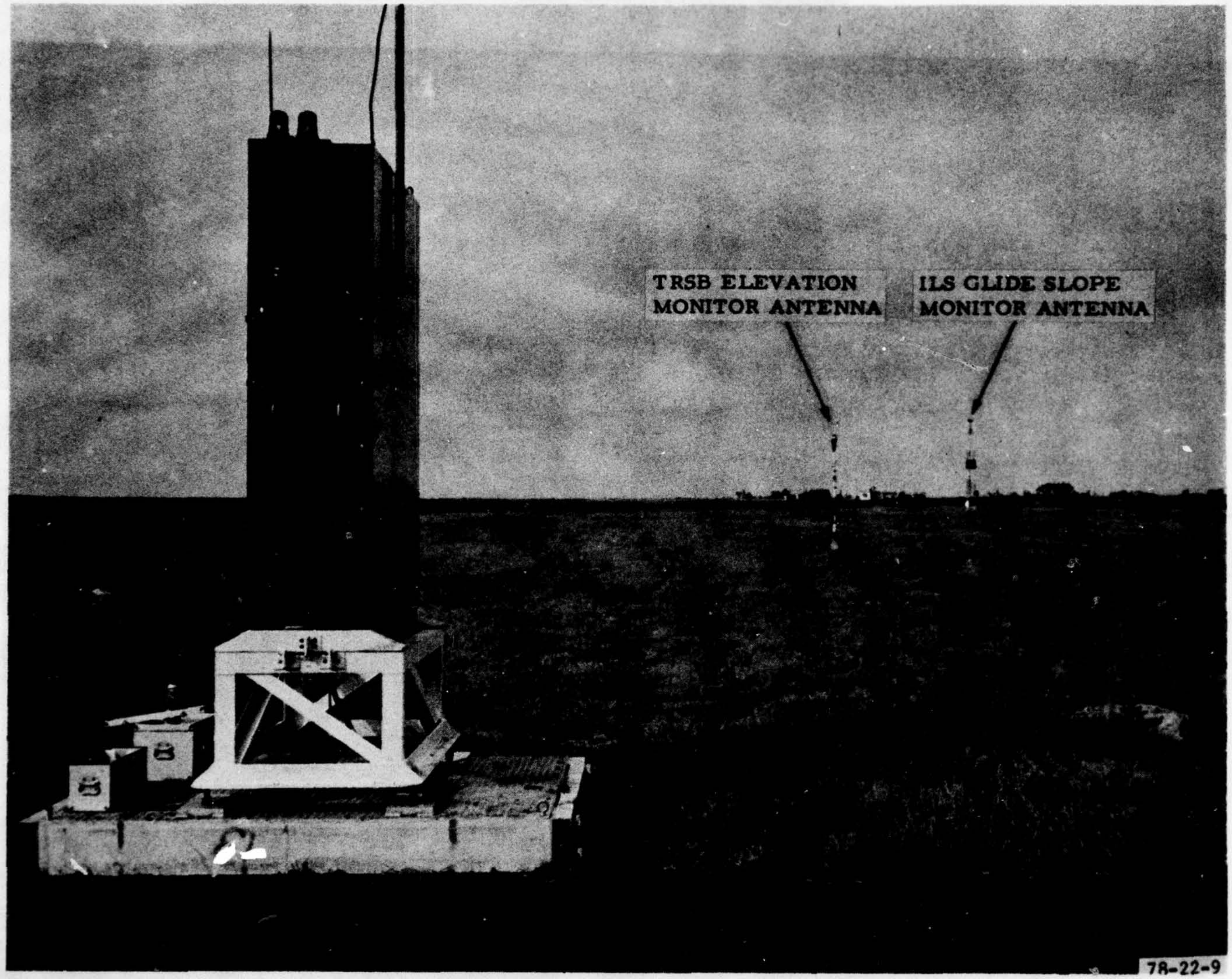


FIGURE 8. TRSB ELEVATION SUBSYSTEM AND MONITOR

FIGURE 9. TRSB INSTALLATION PROCESS

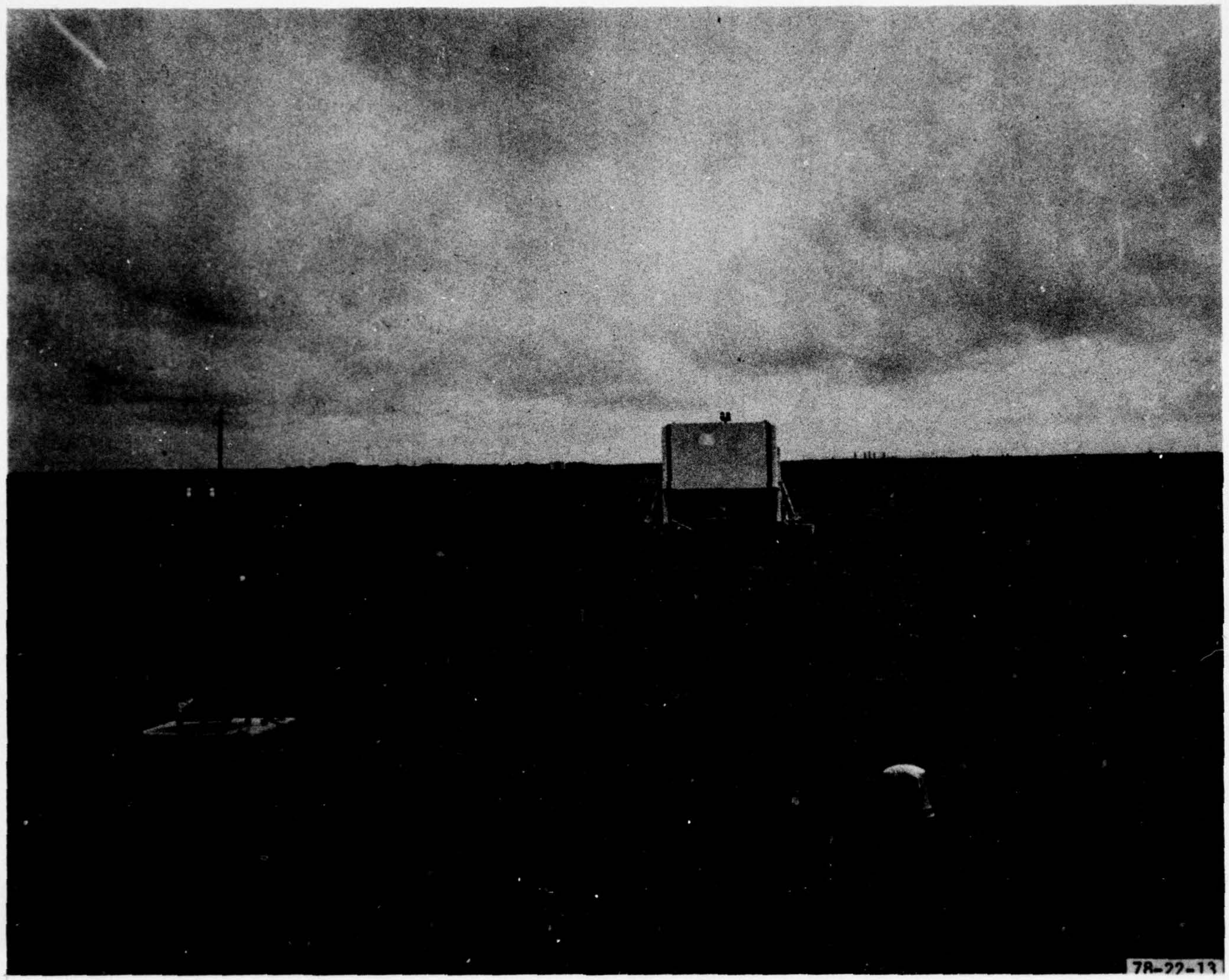


FIGURE 10. TRSB AZIMUTH SUBSYSTEM AND MONITOR

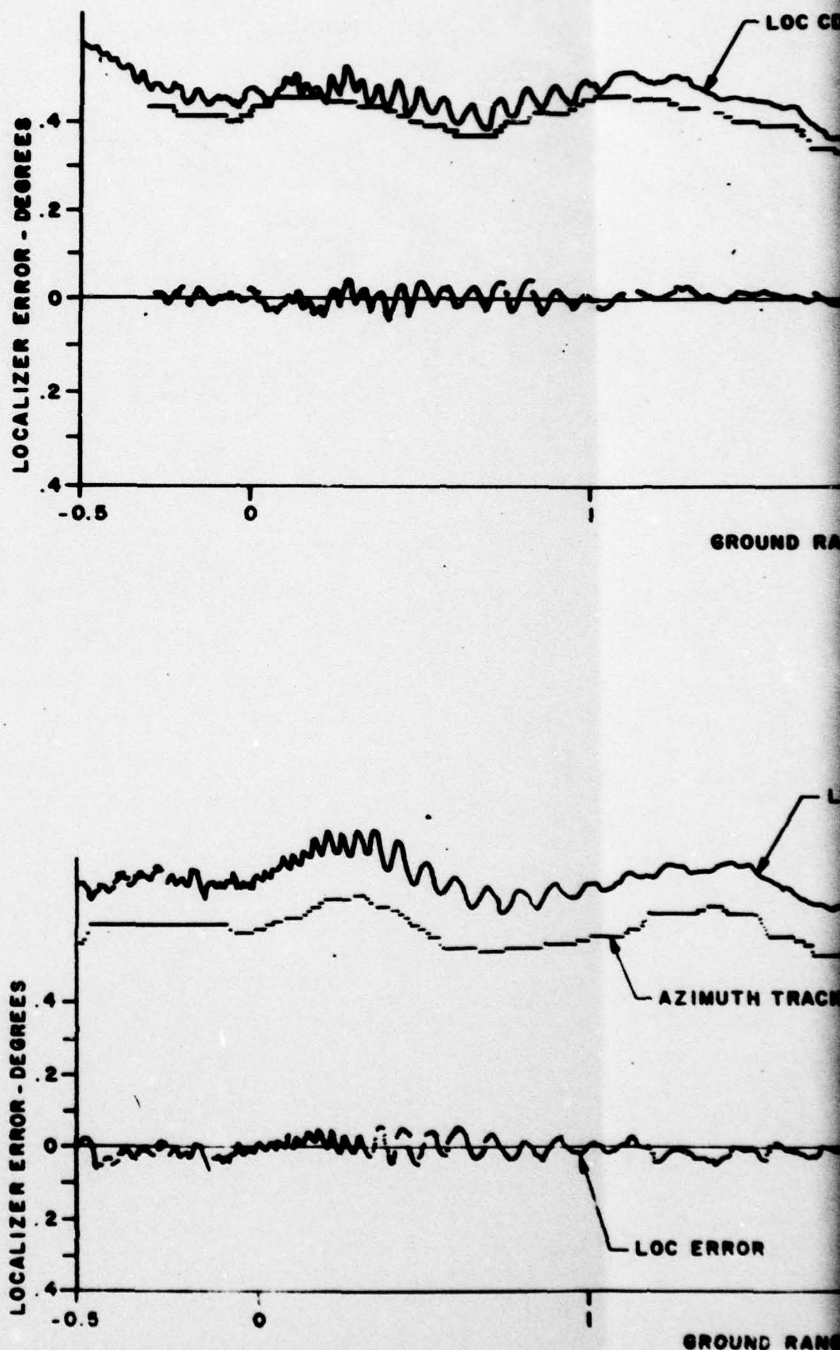
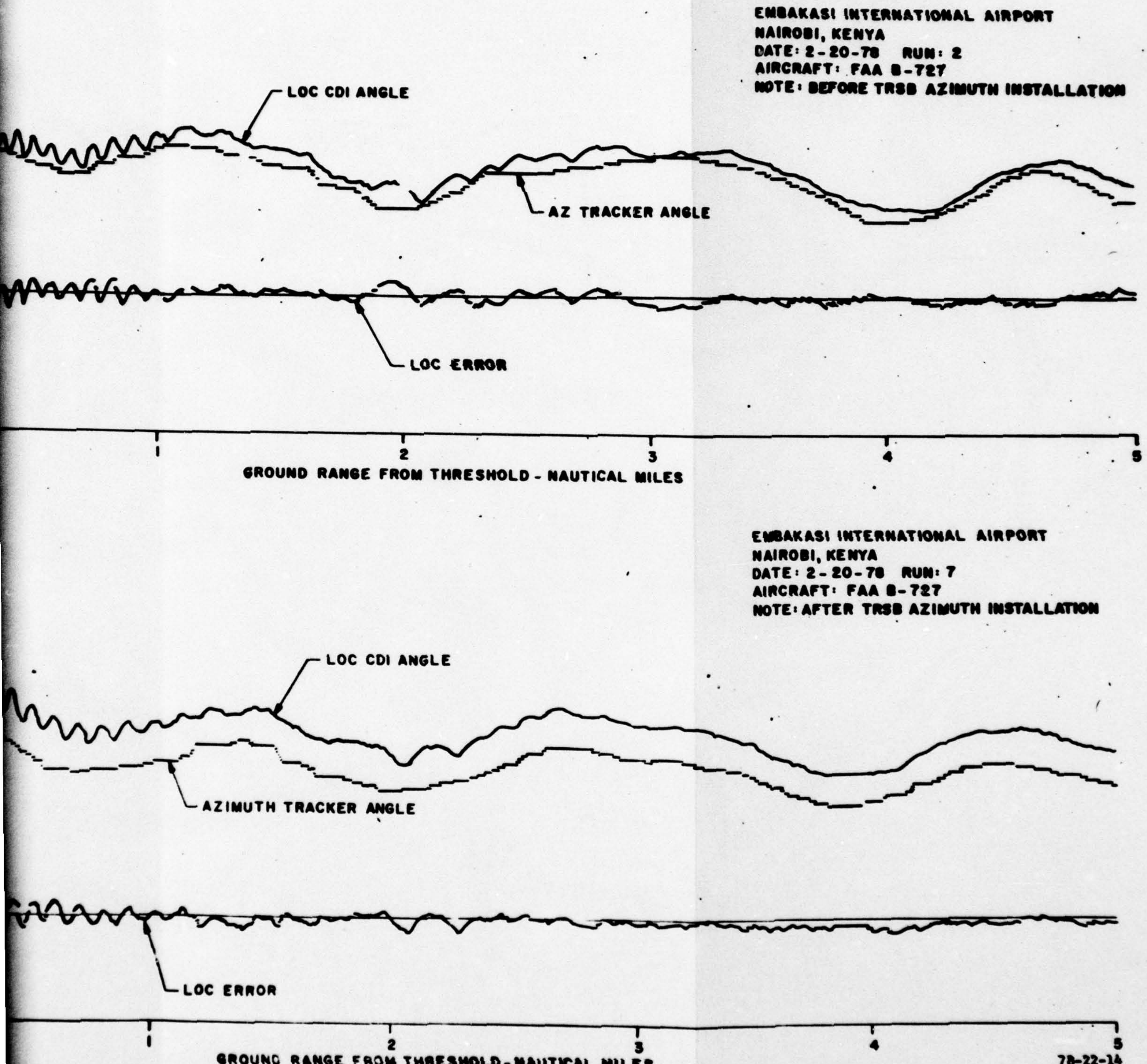


FIGURE 11. ILS LOCALIZER COURSE STRUCTURE



ILS LOCALIZER COURSE STRUCTURE RECORDING BEFORE AND AFTER TRSB AZIMUTH ANTENNA INSTALLATION

2

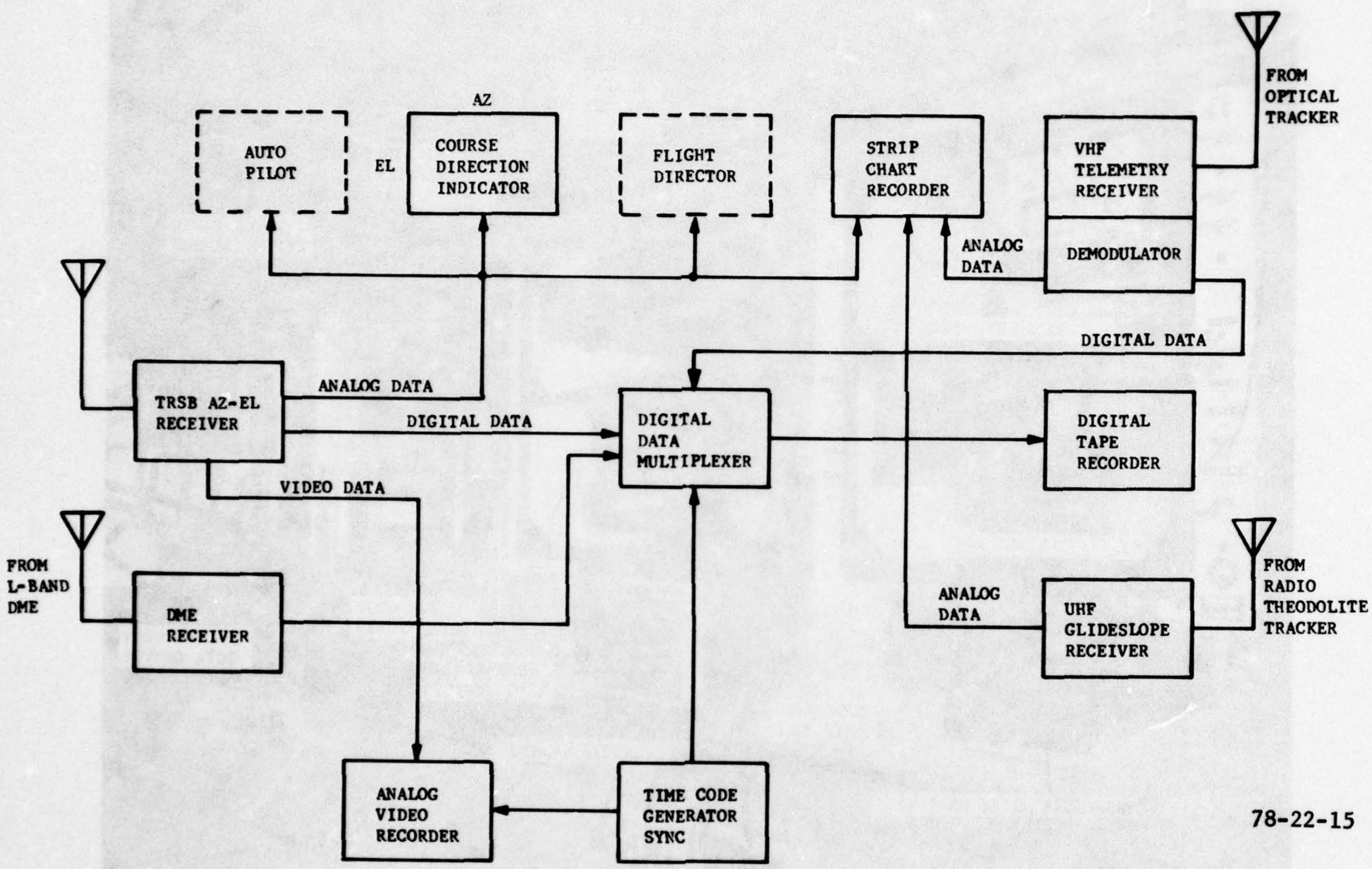


FIGURE 12. TRSB AIRBORNE TESTBED INSTRUMENTATION

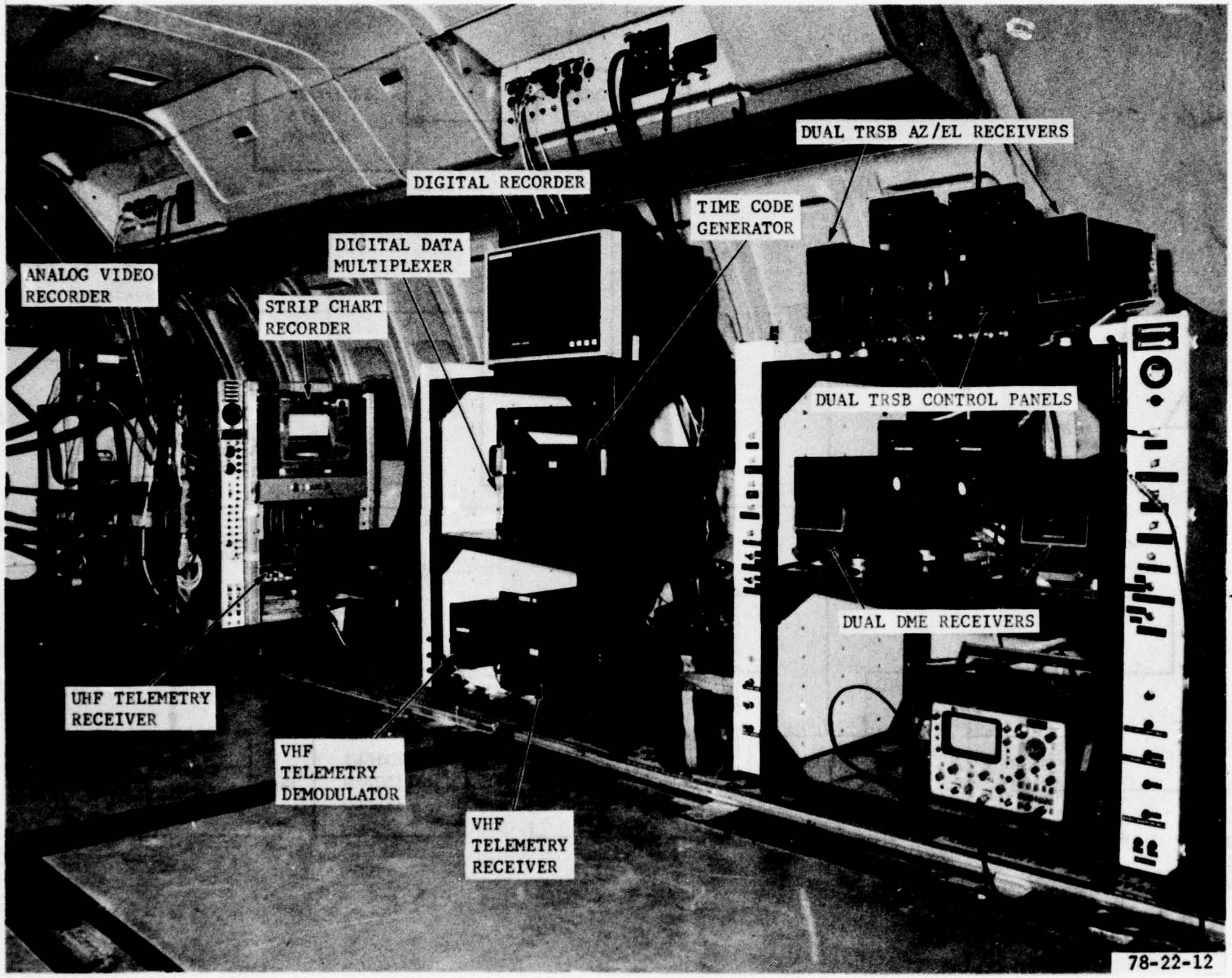


FIGURE 13. TRSB EQUIPMENT AND INSTRUMENTATION INSIDE BOEING 727 TESTBED AIRCRAFT

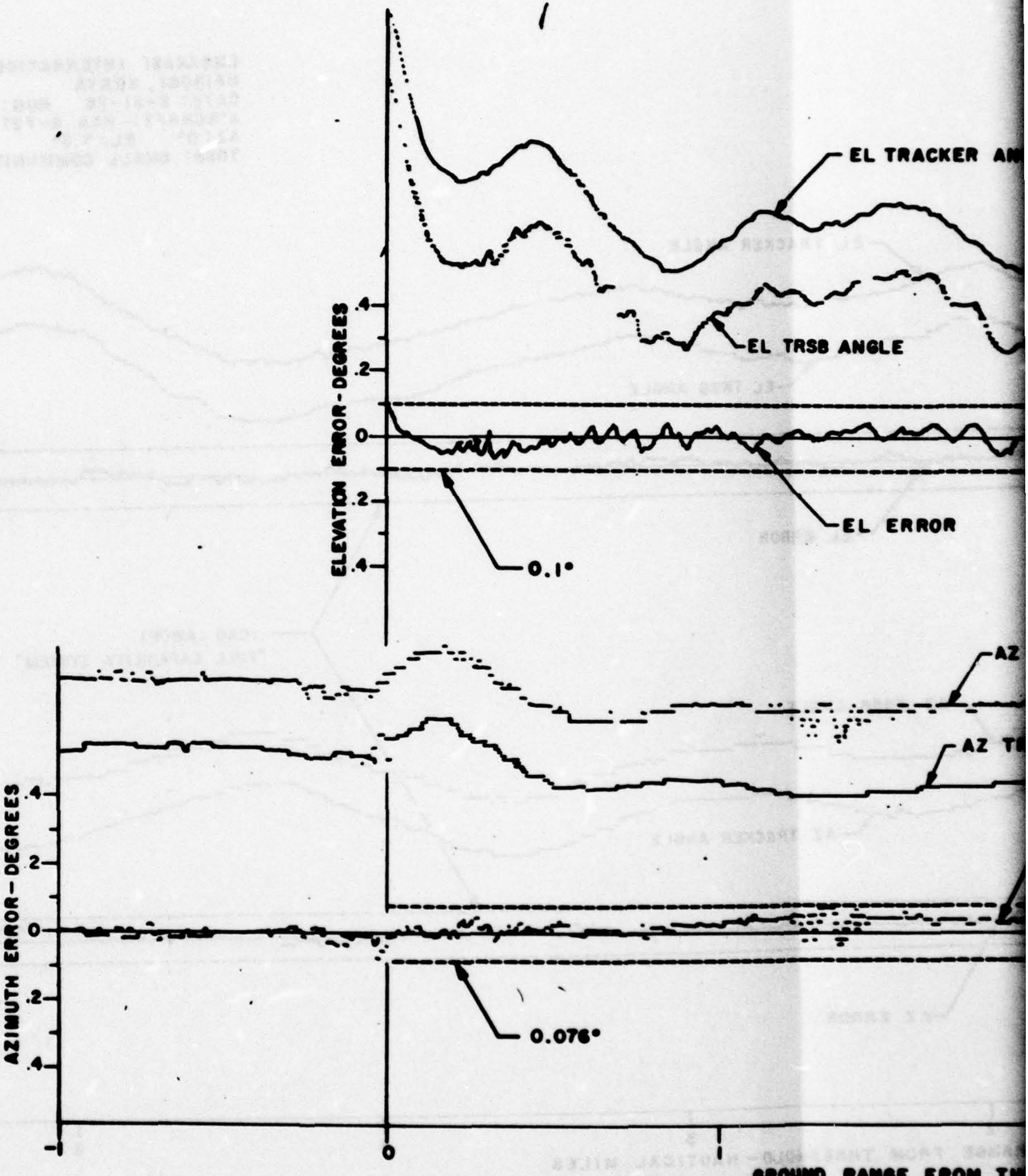


FIGURE 14. SAMPLE DATA P

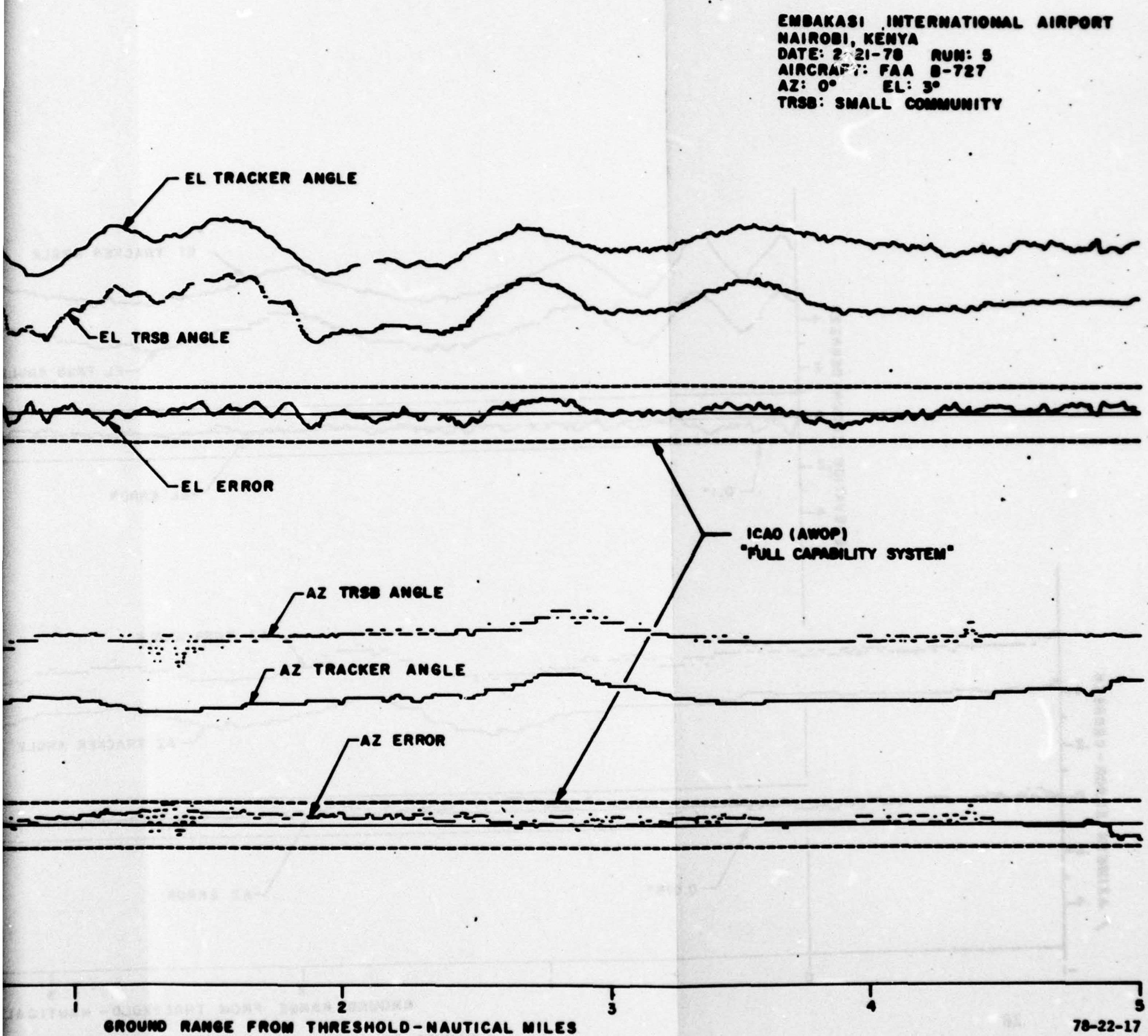


FIGURE 14. SAMPLE DATA PLOT FOR 3° CENTERLINE APPROACH

2

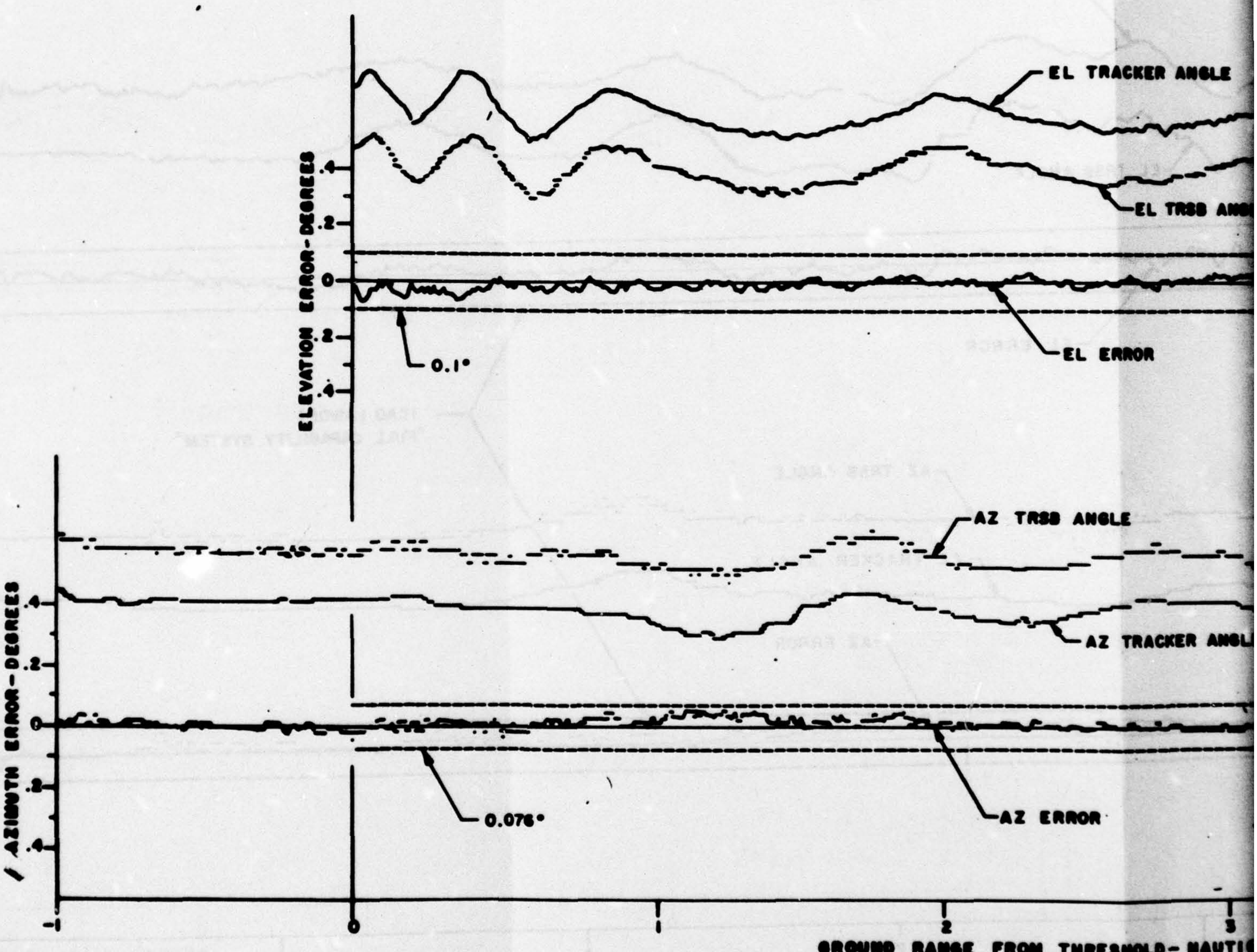
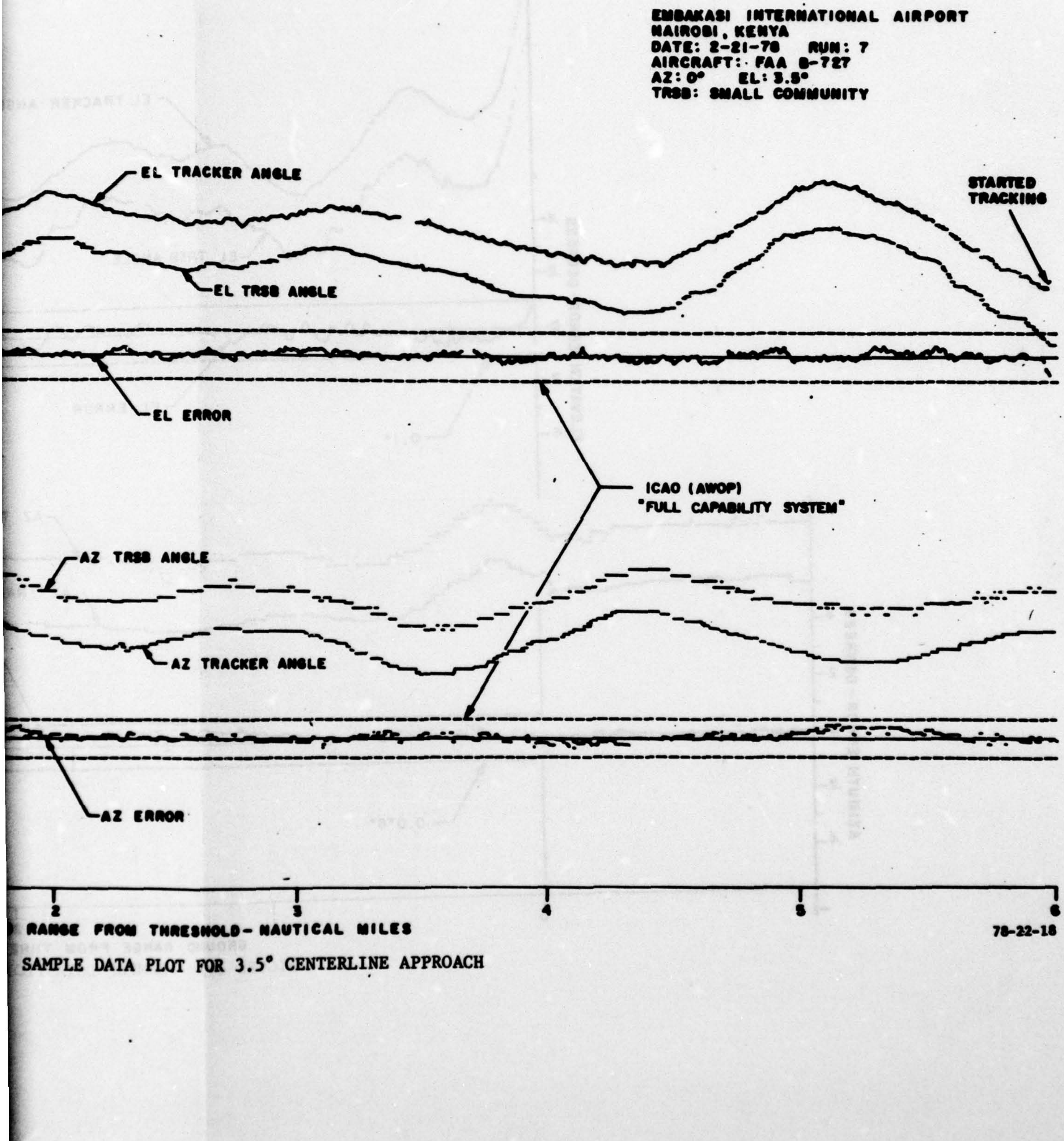


FIGURE 15. SAMPLE DATA PLOT FOR 3.5° CEN



SAMPLE DATA PLOT FOR 3.5° CENTERLINE APPROACH

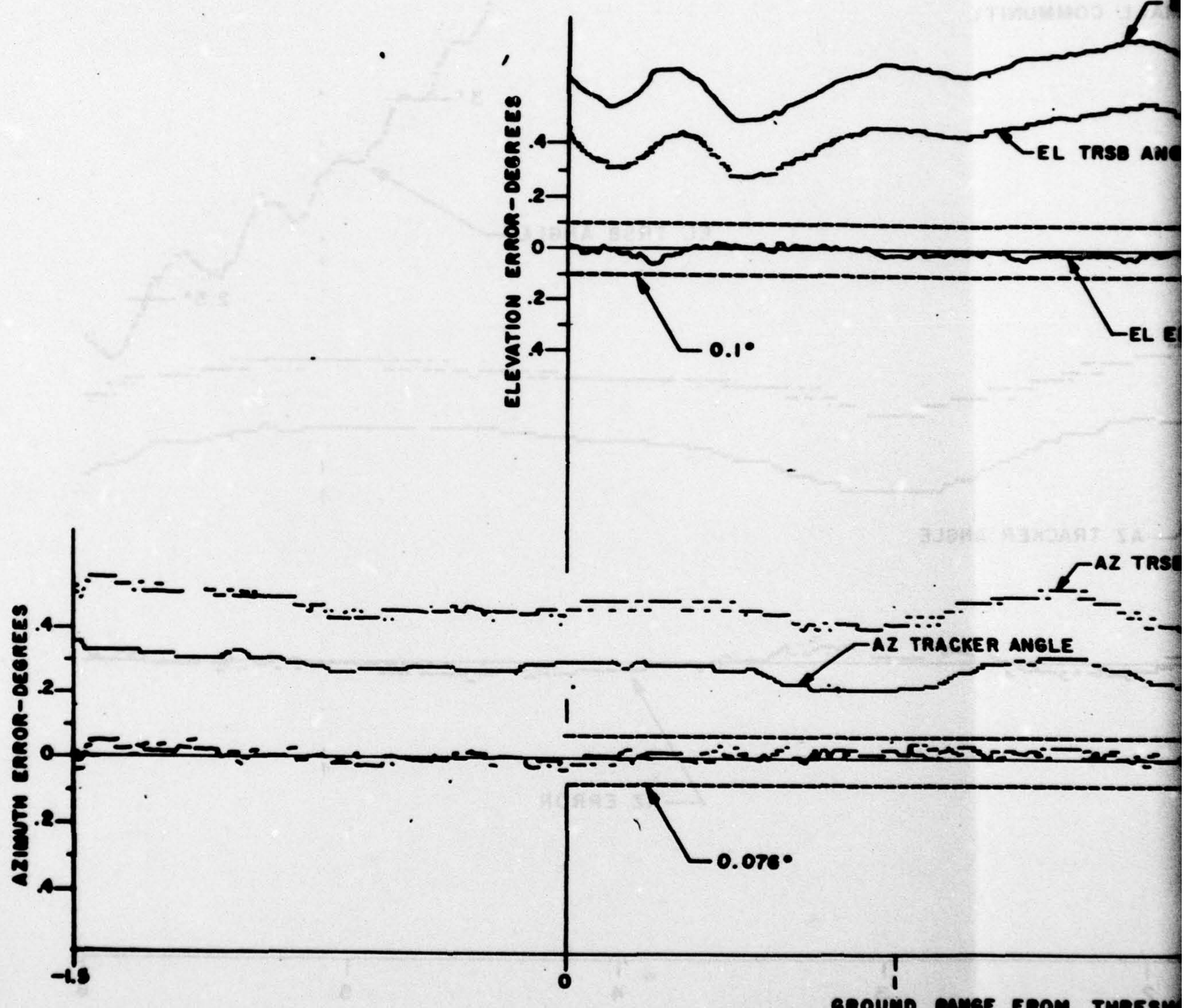
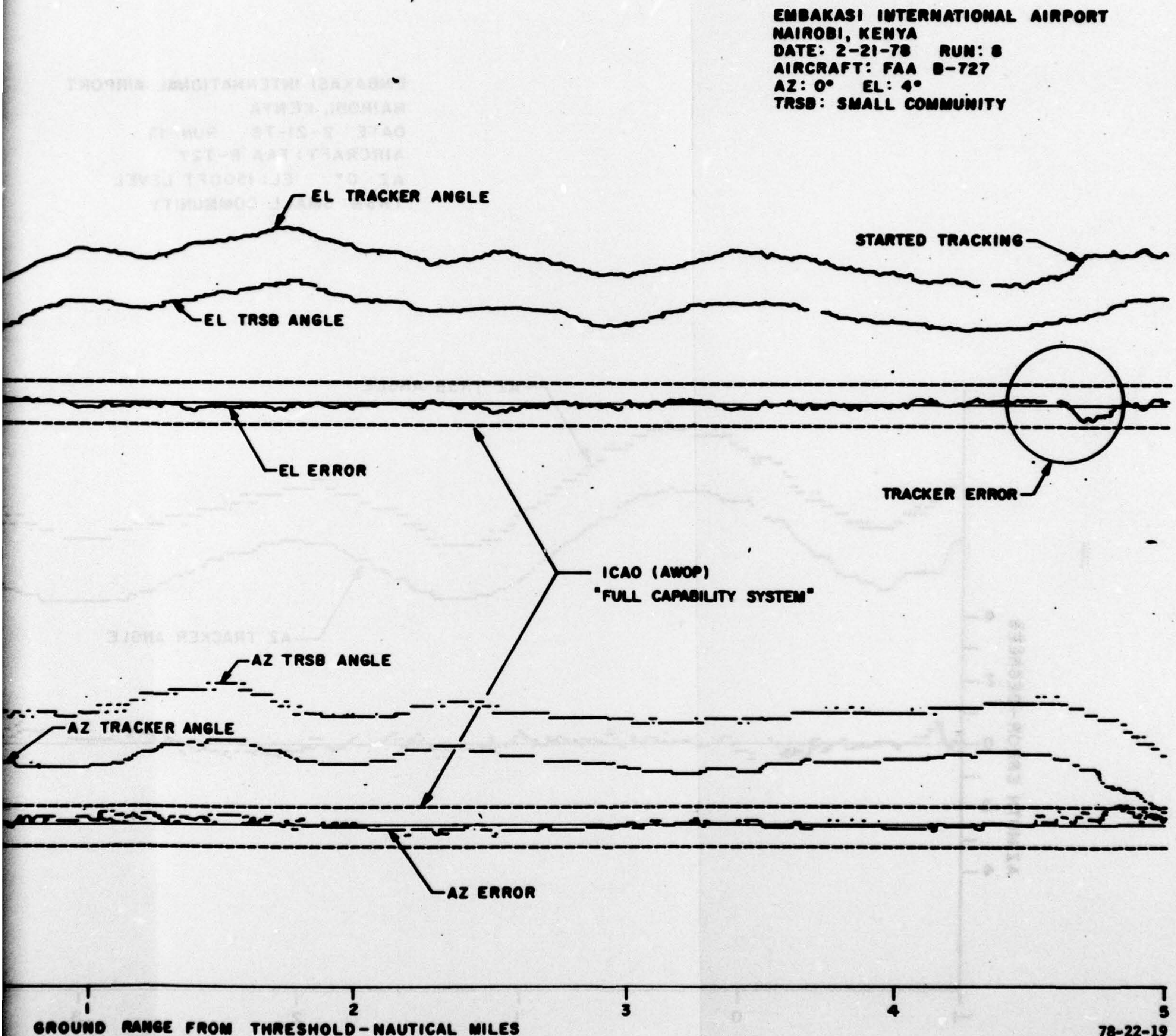


FIGURE 16. SAMPLE DATA PLOT FO



URE 16. SAMPLE DATA PLOT FOR 4° CENTERLINE APPROACH

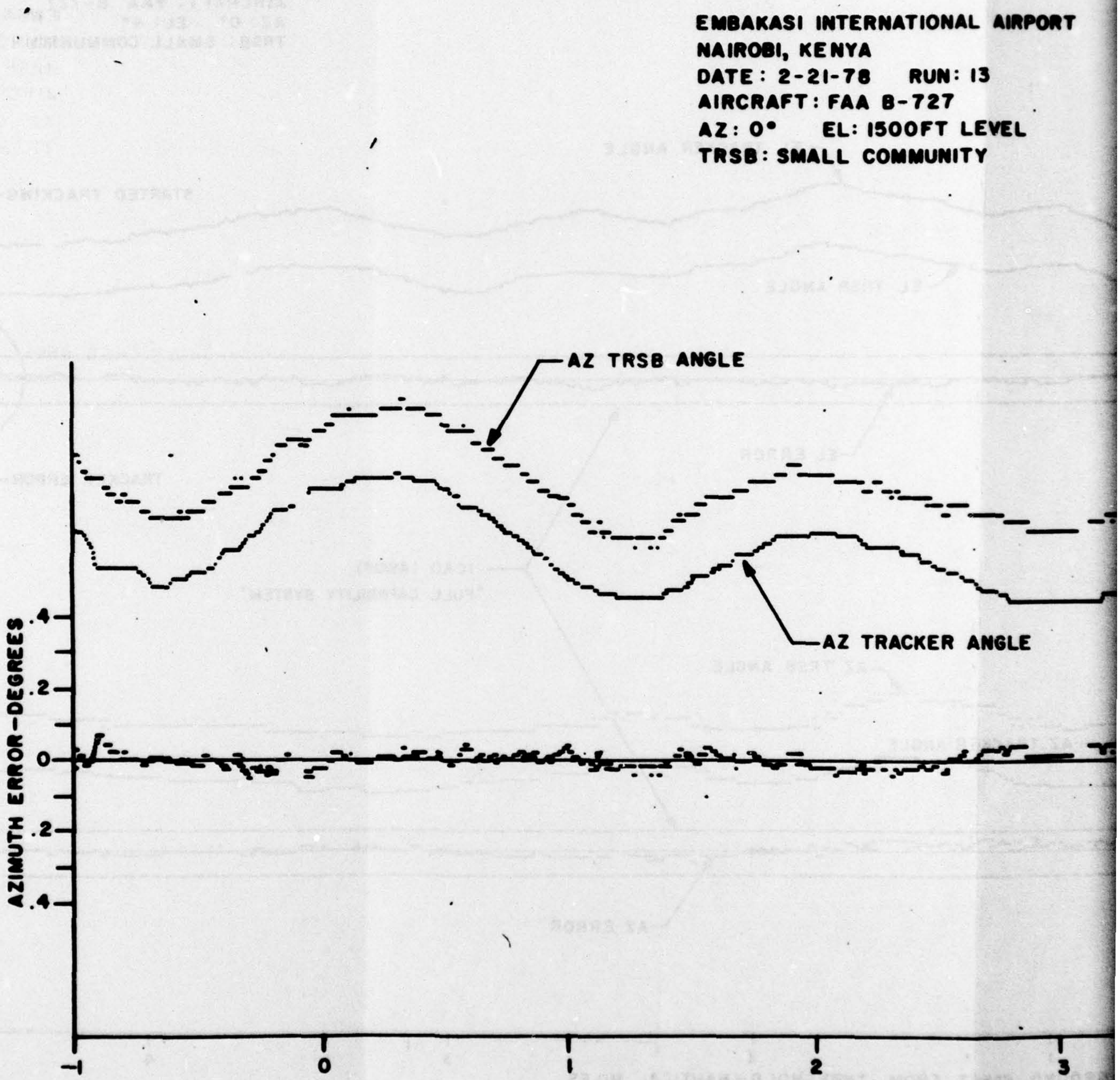
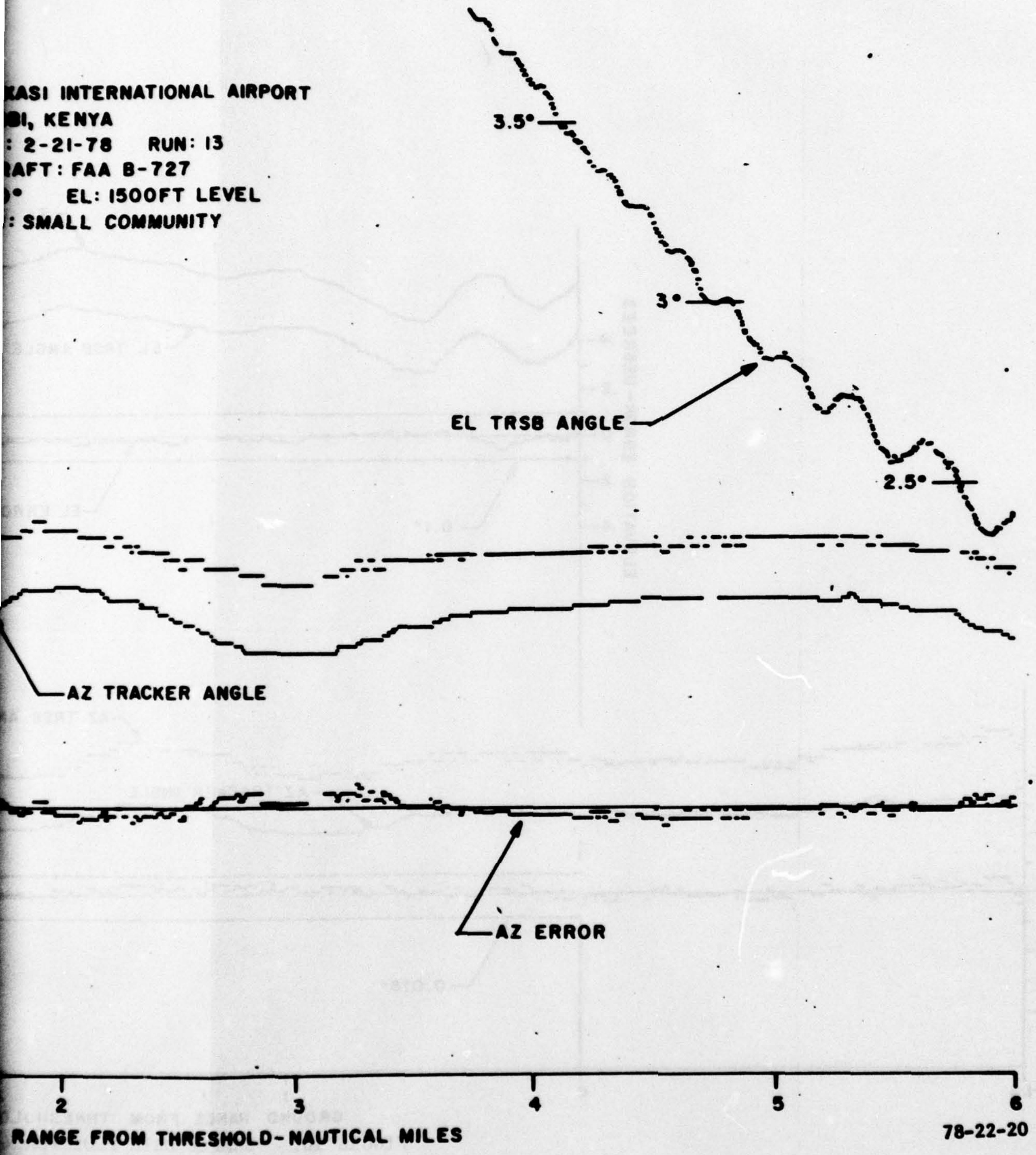


FIGURE 17. SAMPLE DATA PLOT FOR 1500-FOOT LEV



LE DATA PLOT FOR 1500-FOOT LEVEL CENTERLINE RADIAL

2

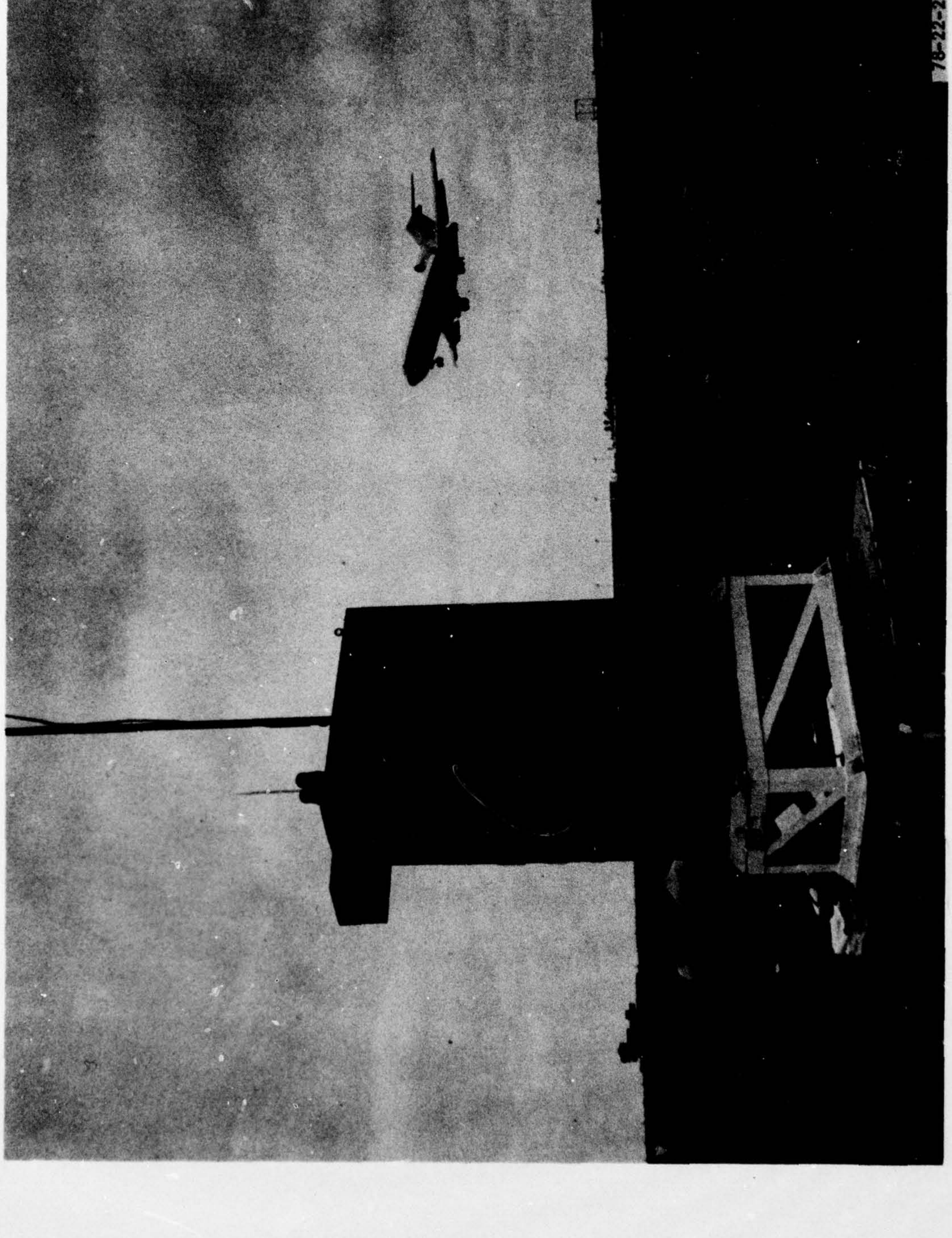
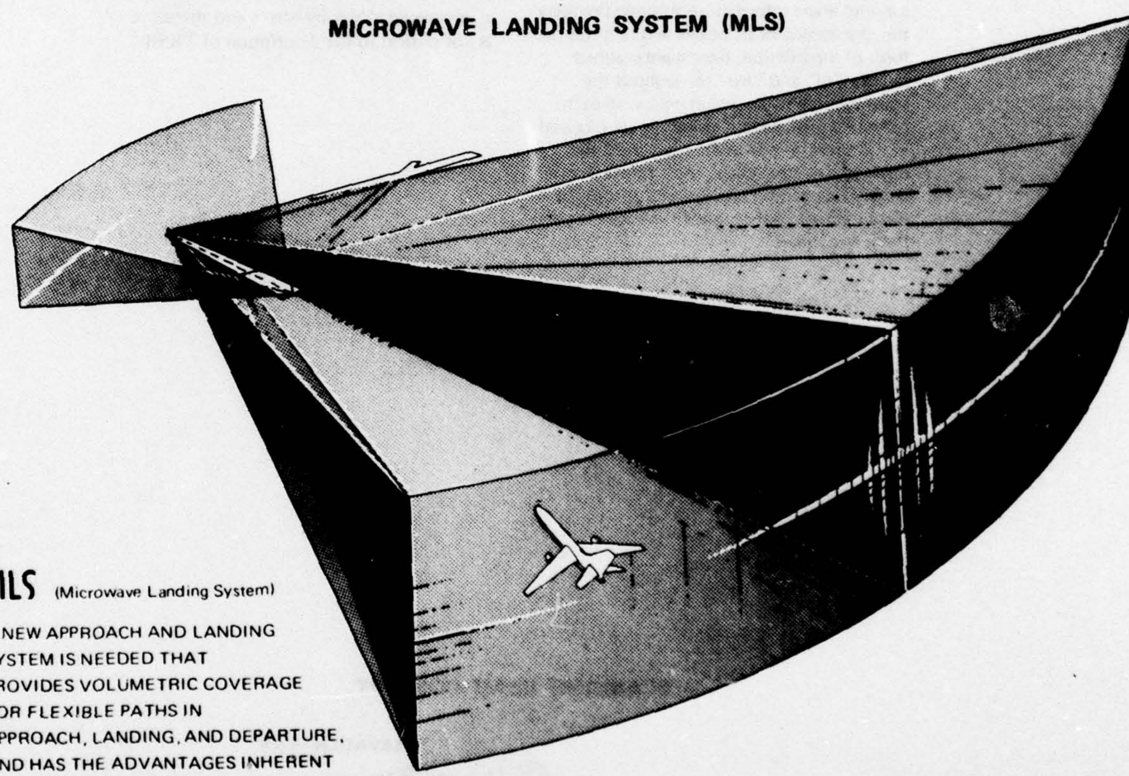


FIGURE 18. TYPICAL TRACKED APPROACH

APPENDIX A

MICROWAVE LANDING SYSTEM (MLS)



MLS (Microwave Landing System)

A NEW APPROACH AND LANDING SYSTEM IS NEEDED THAT PROVIDES VOLUMETRIC COVERAGE FOR FLEXIBLE PATHS IN APPROACH, LANDING, AND DEPARTURE, AND HAS THE ADVANTAGES INHERENT WITH OPERATING AT MICROWAVE FREQUENCIES

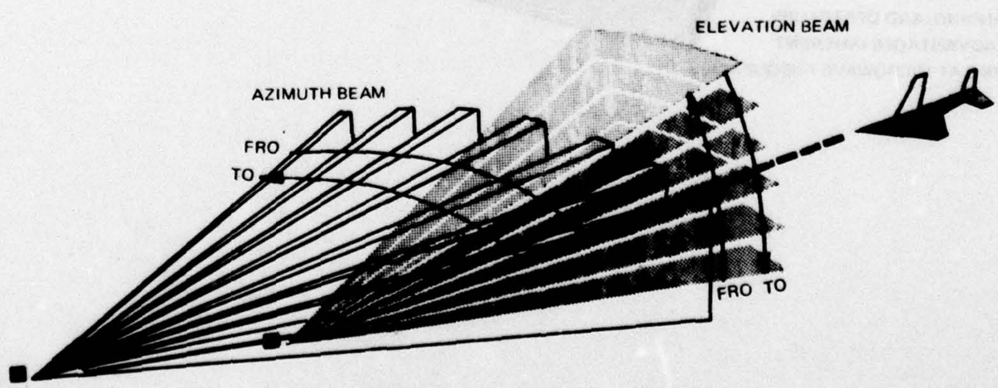
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data (such as wind speed and direction, site data, and system status).

FAN BEAMS PROVIDE ALL ANGLE GUIDANCE (APPROACH AZIMUTH, ELEVATION, FLARE, AND MISSED APPROACH). The TRSB ground transmitter supplies angle information through precisely timed scanning of its beams and requires no form of modulation. Beams are scanned rapidly "to" and "fro" throughout the coverage volume as shown below. In each complete scan cycle, two pulses are received in the aircraft—one in the "to" scan, the other in the "fro" scan. The aircraft receiver derives its position angle directly from the measurement of the time difference between these two pulses.

RANGE IS COMPUTED IN THE CONVENTIONAL MANNER. TRSB proposes to use L-Band Distance Measuring Equipment (DME) that is compatible with existing navigation equipment. It provides improved accuracy and channelization capabilities. The required 200 channels can be made available by assignment or sharing of existing channels, using additional pulse multiplexing. The ground transponder is typically collocated with the approach azimuth subsystem.

NOTE: The DME (ranging) function is not discussed in detail because it is independent of angle guidance subsystems and therefore **is not critical to the description of TRSB.**

SCANNING BEAM CONCEPT



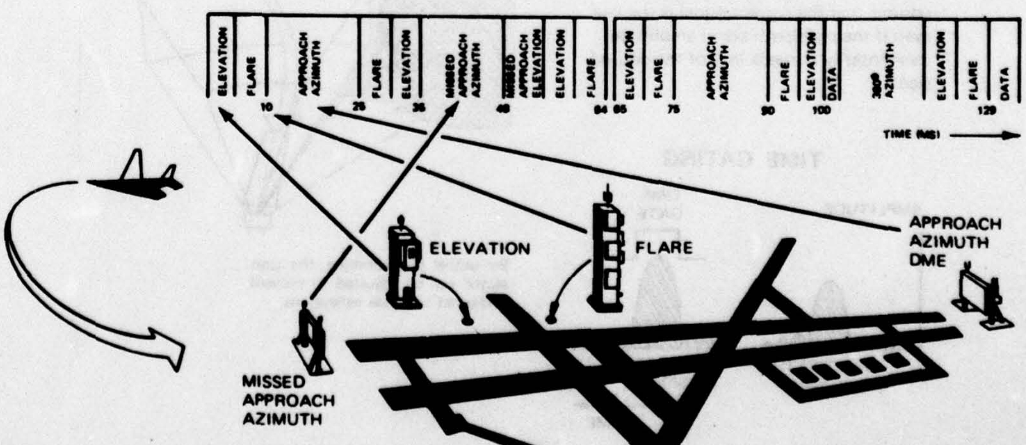
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

TRSB USES A TIME-SEQUENCED SIGNAL FORMAT FOR ANGLE AND DATA FUNCTIONS. Angle and data functions (that is, approach azimuth, elevation, flare, missed-approach guidance, and auxiliary data) are sequentially transmitted by the ground station on the same channel. Primary operation is C-band, with 300 KHz spacing between channels. However the format is compatible with Ku-Band requirements. (Note: DME is an independent function on a separate frequency and is not a part of this format.)

THE SIGNAL FORMAT IS DESIGNED TO ALLOW A MAXIMUM DEGREE OF FLEXIBILITY. Functions can be transmitted in any order or combination to meet the unique operational needs of each site. This flexibility is made possible by a function preamble identification message. This message sets the airborne receiver to measure the angle or decode the data function that will follow. The ordering or timing of transmissions, therefore, is not important. This flexibility permits individual functions to be added or deleted to meet specific airport requirements. It also permits any TRSB airborne receiver to operate with any ground system. The only requirements are that a minimum data rate (minimum number of to-fro time-difference measurements per second) be maintained for each angle function, and that these measurements be relatively evenly distributed in time. An example of two 64-millisecond sequences of a configuration that utilizes all available functions is illustrated below.

THE TRSB FORMAT PROVIDES FOR CURRENT AND ANTICIPATED FUTURE REQUIREMENTS. Included are

- Proportional azimuth angle guidance to ±60° relative to runway centerline at a 13.5-Hz update rate (that is, data are renewed 13.5 times each second.)
- Proportional missed-approach azimuth guidance to ±40° relative to runway centerline at a 6.75-Hz update rate
- Proportional elevation guidance up to 30° with a 40.5-Hz update rate
- Flare guidance up to 15° with a 40.5-Hz update rate
- 360° azimuth guidance with a 6.75-Hz update rate
- Missed-approach or departure elevation function with a 6.75-Hz update rate
- Basic data prior to each angle function (includes function identification, airport identification, azimuth scale factors, and nominal and/or minimum selectable glide slope)
- Auxiliary data (for example, environmental and airport conditions)
- Facility status data
- Ground test signals
- Available time for other data and/or additional *future functions.*

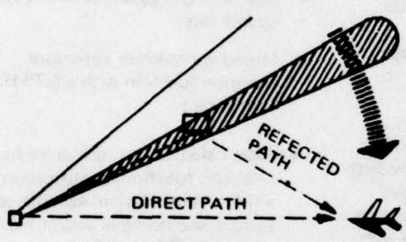


The TRSB signal offers maximum flexibility to meet unique user requirements

TRSB OPERATES EFFECTIVELY IN SEVERE MULTIPATH ENVIRONMENTS. TRSB offers several unique solutions to the multipath problem that has limited the implementation of other landing systems.

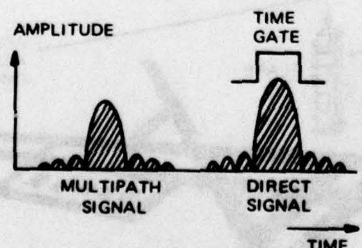
THERE ARE TWO TYPES OF MULTI-PATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival in the aircraft receiver relative to the direct signal.

REFLECTED SIGNALS



OUT-OF-BEAM MULTIPATH. If the angle and therefore the time between the reflected and direct beam are relatively large, the aircraft receiver is subjected to out-of-beam multipath. In this case, the TRSB processor automatically rejects the reflected signal by placing a time gate, as illustrated below, around the desired guidance signal. This ensures that the correct signal is tracked even if the multipath signal amplitude momentarily exceeds that of the desired signal.

TIME GATING



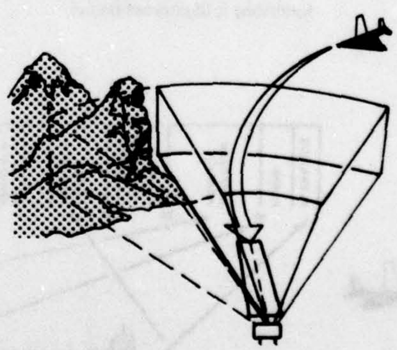
Time gating ensures that the correct signal is tracked, not the reflected one

IN-BEAM MULTIPATH. When the reflected and direct signals reach the aircraft almost simultaneously (the angle of arrival is very small), multipath is said to be in-beam. TRSB combats in-beam multipath by

- Shaping the horizontal pattern of the elevation antenna to reject lateral reflections
- Motion averaging, by utilizing the high data rates of TRSB
- Processing only the leading edge of the flare/elevation beam, which is not contaminated by the ground reflections.

COVERAGE CONTROL IS AVAILABLE TO ELIMINATE MULTIPATH AT EXTREMELY SEVERE PROBLEM SITES. Any MLS system will experience acquisition or tracking problems in those cases where the reflected signal is known to be persistent and greater in amplitude than the direct signal. A TRSB feature called coverage control can be implemented, at no cost, in such cases by simply programming the Beam Steering Unit (BSU). This feature permits a simple adjustment of the ground facility to limit the scan sector in the direction of the obstacle and thereby prevents acquisition of erroneous signals.

SELECTIVE COVERAGE CONTROL



By simple programming, the scan sector can be adjusted to prevent undesired obstacle reflections

TRSB IS A MODULAR SYSTEM WHICH CAN BE CONFIGURED TO MATCH THE NEEDS OF THE USER. A set of phased-array subsystems has been designed that may be installed in any combination to meet the broad range of user requirements.

The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide guidance signals-in-space of uniform quality in all airport environments.

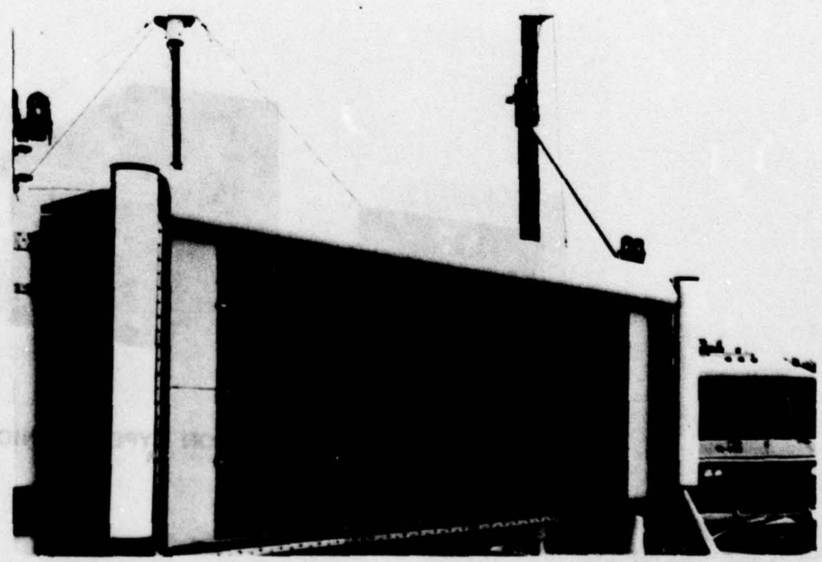
NOTE: DME is an independent subsystem which is combined with appropriate azimuth and elevation subsystems to make up the total guidance system.

GROUND ANGLE SUBSYSTEMS

SUB-SYSTEM	NOMINAL BEAMWIDTH (DEGREES)	COVERAGE (DEGREES) *	PRINCIPAL APPLICATIONS
Azimuth	1	Up to ±60	Approach Azimuth; Long Runways
Azimuth	2	Up to ±60	Approach Azimuth; Intermediate Length Runways
Azimuth	3	Up to ±60	Approach Azimuth; Short Runways Missed Approach Azimuth
Elevation	0.5	Up to 15	Flare
Elevation	1	Up to 30	Elevation (Severe multipath sites)**
Elevation	2	Up to 30	Elevation (Less severe multipath sites)**

* Coverage determined by Beam Steering Unit (BSU) for all arrays.

** See multipath discussion.



Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

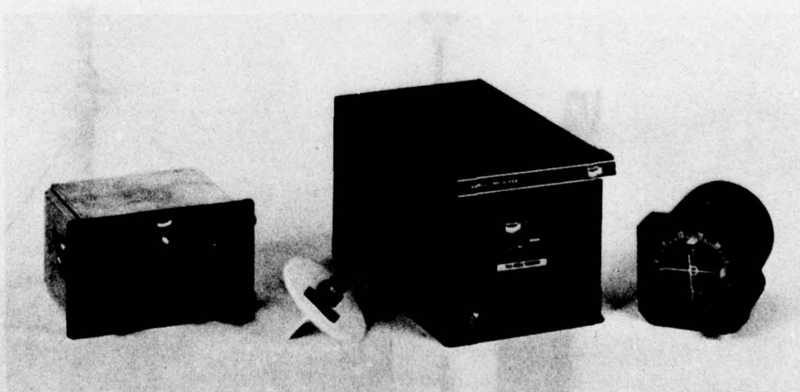
AIRBORNE RECEIVER DESIGNS ALSO STRESS THE MODULARITY CONCEPT. Users need only procure what is necessary for the services desired from any ground facility. To obtain approach and landing *guidance at the lowest cost, an aircraft needs* only an antenna and a basic receiver-processor unit operating with existing ILS displays. An air-transport category aircraft equipped for operation to low-weather minimums will carry redundant equipment and, in the future, advanced displays to fully utilize all of the inherent operational capabilities provided by TRSB.

The 200-channel TRSB angle receiver-processor provides angle information from the scanning beam azimuth and elevation subsystems and decodes the auxiliary data for display. Special monitoring ensures the integrity of the receiver output.

A second airborne unit is the DME. It is channeled to operate with the angle receiver-processor and provides a continual readout of distance.

Both the angle receiver-processor and the DME provide standard outputs to existing flight instruments and autopilot systems. An optional airborne computer would be used to generate curved or segmented approaches based on TRSB position information.

AIRLINE TYPE AVIONICS



GENERAL AVIATION TYPE AVIONICS

TRSB CAN PROVIDE ALL-WEATHER LANDING CAPABILITY AT MANY RUNWAYS THAT PRESENTLY DO NOT OFFER THIS SERVICE. This is made possible by

- The proposed channel plan, which contains enough channels for any foreseeable implementation
- High system integrity and precision
- Minimum siting requirements.

THE LARGE COVERAGE VOLUME PROVIDES FLIGHT PATH FLEXIBILITY. Transition from en route navigation is enhanced through the wide proportional coverage of MLS. Such flexibility in approach paths, coupled with high-quality guidance, can be used to achieve

- Improvements in runway and airport arrival capacity
- Better control of noise exposure near airports
- Optimized approach paths for future V/STOL aircraft
- Intercept of glide path and of runway centerline extended without overshoot
- Lower minimums at certain existing airports by providing precise missed-approach guidance
- Wake vortex avoidance flight paths.

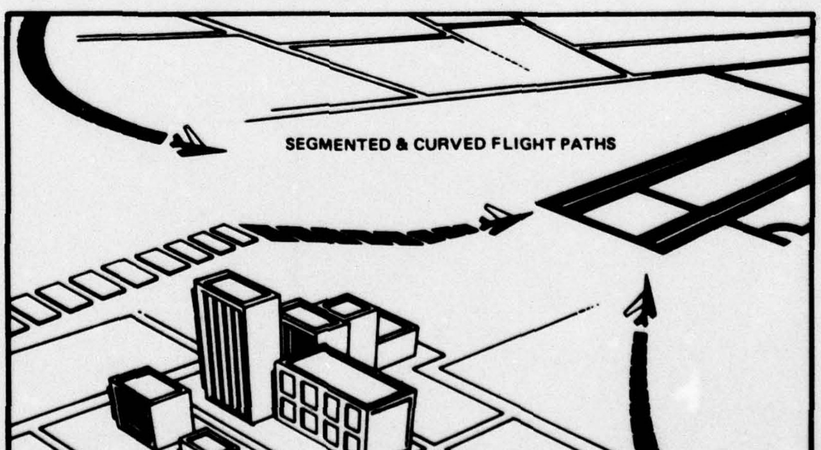
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

TRSB SPANS THE ENTIRE RANGE OF APPROACH AND LANDING OPERATIONS FOR ALL AIRCRAFT TYPES. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. The particular needs of users, ranging from general aviation to major air carriers, are accommodated. TRSB is adaptable to special military applications, such as transportable or shipboard configurations on a compatible basis with civil systems.

HIGH RELIABILITY, INTEGRITY, AND SAFETY OF TRSB ARE ENHANCED BY SEVERAL IMPORTANT FEATURES. These include

- Simple TRSB receiver processing
- Multipath immunity features on the ground and in the airborne receiver-processor
- A comprehensive monitoring system that verifies the status of all subsystems and the radiated signal. Status data are transmitted to all aircraft six times each second.
- Coding features, such as parity and symmetry checks, that prevent the mixing of functions.

TRSB PROVIDES CATEGORY-III QUALITY GUIDANCE. TRSB signal guidance quality has already been proved via demonstration of fully automatic landings, including rollout, in a current commercial transport aircraft (Boeing 737) and an executive jet (North American Sabreliner).



TRSB provides precision guidance for curved and segmented approaches for noise abatement and traffic separation, as well as for autoland and rollout